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UNDERSTANDING FARM HOUSEHOLD-LEVEL DECISION MAKING: THE VAQUERIAS CASE

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UNDERSTANDING FARM HOUSEHOLD-LEVEL DECISION MAKING: THE VAQUERIAS CASE

by

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THE VAQUERIAS CASE

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In a situation of limited resources, climate and economic uncertainty typical of the agricultural business, a systems approach is needed to build appropriate decision-making aids. However, few studies have been made about how farmers make decisions. In this work it was constructed an ethnographic linear programming (ELP) model that represents a typical farming systems; different scenarios were simulated by using inputs from crop simulation results; and those scenarios were used to compare farmers responses in order to learn about their decision making criteria. Results include the description of the current decision making environment, after the experience of the so-called Vaquerías Project; an ELP model of the ex-ejido farms in the Northeastern region of Mexico; and a crop rotation proposal that maximize the family annual income. By using sequential simulation, crop simulation models and an Ethnographic Linear Programming model it achieves realistically mimic the system. Risk management and personal concerns were found as farmers' main criteria for decision making, rather than income maximization by itself. Training of technician and community leaders on computer skills is proposed as an apropriate way to help people taking advantage of computer model.

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En una situación de recursos limitados y de incertidumbre climática y económica, típica de las empresas agrícolas, un enfoque de sistemas podría ser necesario para construir adecuados apoyos para tomar decisiones. Sin embargo, muy poco se ha estudiado sobre la forma en que los agricultores toman decisiones En este trabajo se construyó un modelo de Programación Lineal Etnográfica (PLE) que representa un típico sistema agrícola de las granjas de la región; se simularon diferentes escenarios, usando insumos provenientes de modelos que simulan el crecimiento de cultivos, y se usaron esos escenarios para compararlos con la decisiones tomadas por los agricultores. Todo esto para tratar de identificar, entender y aprender sobre los principales criterios que rigen la toma de decisiones. Los resultados incluyen la descripción del medio ambiente actual en el que se toman las decisiones, después de la experiencia del llamado "Proyecto Vaquerías"; un modelo de PLE de la típica granja del exejido Vaquerías, y una propuesta de rotación de cultivos que maximiza el ingreso familiar anual. Usando de manera secuencial los modelos que simulan el crecimiento de cultivos y el modelo de Programación Lineal Etnográfica que simula la economía de la granja, se logró imitar el sistema de manera realista. Se encontró que los conceptos de "Seguridad" y "Riesgo" en

un ambiente incierto, y prioridades personales (como disponer de tiempo libre), tenían mucho más peso en la toma de decisiones que la búsqueda de maximización del ingreso. Se propone la participación activa de las Universidades en la formación de grupos de aprendizaje y en la búsqueda de estrategias apropiadas para el entrenamiento de técnicos y líderes comunitarios, en el desarrollo de habilidades computacionales, para el uso de modelos útiles para la toma de decisiones en las empresas agrícolas.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Problem Statement

With the very limited resources, climate and economic uncertainty typical of the agricultural business, Mexican small farmers are facing a new commercial environment without historical experiences in their new role as the decision makers in business administration; moreover, they lack time to build that experience strictly by empirical observations and tests. In such a situation, a systems approach is needed to build appropriate decision-making aids.

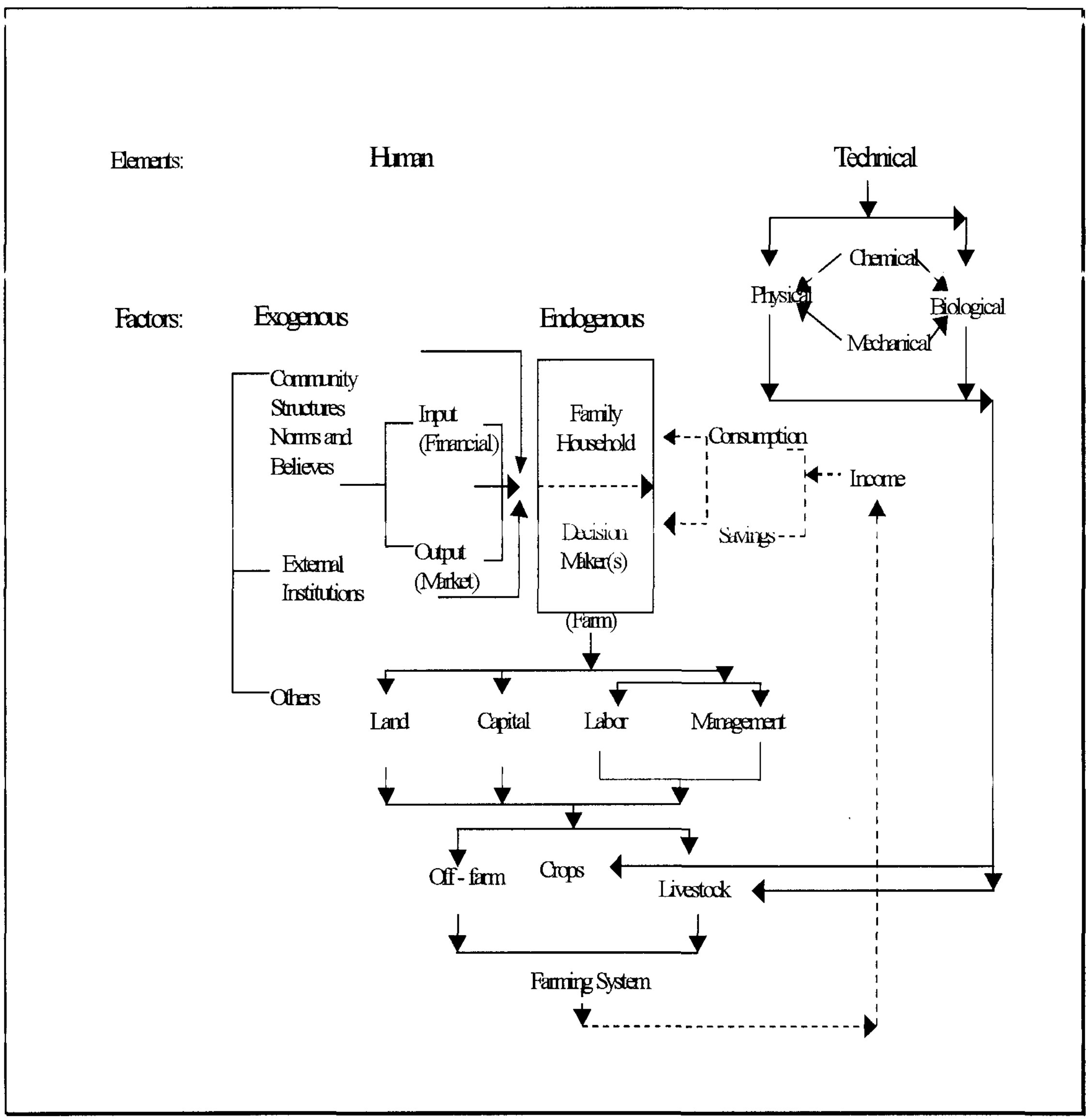
Over the last 30 years, a wide range of research has been conducted on diverse crops, including work to develop a series of "production models" of different types (E. Matthaeus, W. Mirschel, H. Kretschmer, K. Kuenkel, I. Klank, 1986; F. W. T. Penning De Vries & H. H. Van Laar, 1982; J. R. Williams, C.A. Jones, and P.T. Dyke, 1984). In particular, important progress has been made in developing computer simulation models of biological processes. Apparently, these models can be used to valuably improve management decisions by using a systems approach to simulate different scenarios and reduce economic risk. However, their adoption for use by farm managers is almost null in México, in spite of the existence of favorable factors.

For unknown reasons, Mexican small farm owner-managers do not take advantage of the opportunity of being helped by these models to make decisions. This is the research issue to which this dissertation is addressed.

During the last decade, Mexican farmers have seen their own world turn almost up side down. Before that, around 80% of Mexican territory and arable fields were State-owned land; people working on it could not hold it as property. Constitutional changes toward a private property policy, commercial land and free markets were just the beginning of multiple changes. Free market prices are eliminating all guaranteed prices for basic crops and increasing input costs. Management of public irrigation districts is being transferred to their users: small farmers, who have now to assume their role as decision-makers.

Immersed in such a sea of changing conditions, farmers have to face not only the old known risk of extreme weather, but also the new uncertainty of free market and global competition without a paternalistic government; they have to play their decision-maker role with a more "entrepreneurial" style. Unfortunately, there is no historical background of that issue in México. Practically, it is safe to say that the best way to run the new Mexican crop-production agribusiness is unknown. Help to support their decisions should be welcome. Models (crop models, farm models, even region or river basin models) can be highly useful for that purpose; however, some gaps must be filled. Finding ways to make a system modeling approach accessible for gaps must be filled. Finding ways to make a system modeling approach accessible for these new decision makers becomes so important. That is the area where this dissertation seeks to make a contribution.

Figure 1-1. Norman's model to define a farming system (D. W. Norman, 1986)



Norman (1986) defined a farming system through an excellent model shown in 1-1. That model divides the whole system into two elements: human and technical. Within the technical element are physical and chemical factors, and under the human element, there are exogenous (external) and endogenous (internal) factors. Located in the center of the model is the farmer in his/her role of decision maker: our interest. As human element, part of the endogenous factor, s/he has to make decisions taking account his/her family's needs and the information s/he receives from the exogenous factors. The farmer makes decisions to apply available resources (land, capital, labor) to his/her productive crop and livestock systems, as well as the off-farm systems, generating his/her very own farming system.

Norman's model shows that the natural, productive systems (crop and livestock) respond to farmer's decisions of resource application according to their physical and chemical natural factors. Knowledge about those factors could certainly help farmer to understand the production system and to predict its possible performance.

Models, as representations of systems (J. W. Jones & J. C. Luyten, 1998), can be and are made at different hierarchical levels. Even if observation is limited to mathematical models, it is possible to find them from molecular to cosmic levels. Yet, if research is constrained to living or biological systems it is possible to find models along the 8 levels (cell, organ, organism, group, organization, community, society, and supranational systems) of the Miller's hierarchical classification (J. G. Miller, 1978; G. A. Swanson & J. G. Miller, 1989).

Lal (1998), focusing on farming situation models, presented a reduced classification of these models into 3 levels: biological plant scale (organism), field scale (group), and whole-farm (organization) models.

Some crop simulation models have been widely tested and proved to satisfactorily simulate crop growth and production (K. J. Boote, J. W. Jones, & G. Hoogenboom, 1998); knowledge and decision aids for informing agricultural producers can be obtained from them. Production, however, is just one of the criteria a farmer has to consider when making a decision. Most farm management decisions are money-oriented (economical and financial); moreover, criteria of quality (market orientation) and sustainability (long term orientation) must be included to stay in business. Crop models are really good and useful, but they are not enough. Farmers need farm models that include both, production models and the other criteria mentioned above.

Farm models have been made with different approaches, such as through object–oriented simulation languages (H. Lal, 1998; M. J. Shaffer, P. N. S. Bartling, & J. C. I. Ascough, 2000). Some have even tried to include economic criteria (H. O. Nyangito, 1995), and also long term productivity, profitability and ecological criteria

(J. Luna, 1994). Much of the work at the farm level is actually focused on just one or some limited aspect of the farm (F. Guerrin, 2001). That is probably because some subsystems of the farm have to be studied at the farm level, but that is not really a farm model. An interesting approach was used by Hansen (1995) and Kelly (1995) in which farm models were linked with crop production models. That way, a reliable crop model expands to include models from other subsystems of the farm. Integration of subsystem models can lead to a better understanding of farm processes and allow the development of a better tool to support farmers' decisions.

Due to the changing situation of Mexican farmers, and to the state of the art of farm model development, publications of farm models that actually simulate farm behavior under Mexican conditions do not exist. Also, there is not enough evidence about how, and how much, economic and financial data information modifies a given optimal result from crop and/or farm models. Finally, there is no empirical evidence about the farmers' decision-making process.

Farm models, as well as other economic models, are commonly based on assumptions according to the economic theory of rational choice; thus, they become rational choice models. When a typical Linear Programming (LP) model runs to maximize utility or minimize costs, assumptions are made that those are the decision makers' priorities. If such models are used by policy makers trying to predict the response or reaction of people (farmers or other decision makers) to a determinate policy, it is not rare for predictions to fail, because there is not enough evidence of farmers (people) rational choice decision-making, while examples abound to support the contrary (H. A. Simon, 1992). Some of the classical assumptions underlying rational choice theory are (M. Zey, 1992):

The individual is antecedent to and independent of the group.

Humans are only self-interested.

Humans act only out of rationality.

Value is subjective.

Humans are utility maximizing.

Utility is subjective.

The Neoclassical view is value-neutral.

The individual is the appropriate unit of analysis.

Organizations function rationally.

Organizations function efficiently.

For decades, economists and management scientists have held the view that individuals and organizations should and will be rational in their decision-making, at least within limits set by their information gathering resources. Organizational behaviorists, on other hand, have found that, although organizations may attempt to make intelligent decisions leading to desirable outcomes, because they are separated by space and time, decision makers are inconsistent in their decision-making processes. Moreover, organizations are hard pressed to overcome problems caused by ignorance, conflict, and ambiguity (J. F. Shapiro, 2001).

When a model, supposedly designed to serve as a decision aid to agricultural producers, is created without an acceptable understanding of the system's behavior, it becomes useless and lacks purpose due either to its inability to describe adequately the system, or to its failure to simulate effectively the behavior it seeks to model.

Research Questions

The above considerations lead to the following questions:

1. Why are crop production models not widely used – alone or within a Decision Support System (DSS) – for Mexican farmers yet?
2. Do economic and financial criteria have significant impact to actually change "optimal" decisions suggested for production models?
3. Are Mexican farmers rational decision makers?
4. What must a DSS include, aside from crop production models, to better support Mexican farmers' decision making?

5. What must a farm model include, aside from crop production models, to better describe Mexican farmers' decision making?

Assumptions

1. Farm and field models can help farmers to better understand their new production and marketing environment.
2. Those models can also help farmers to make better decisions in this new environment to increase profits and reduce economic risk.

Objectives

"The general objective of the current research is to better understand the criteria of the decision making process of Mexican small farmers in order to propose a useful farm model, and to develop a way for farmers to use data and modeling to improve their decisions in their increasingly global commercial free market environment."

Specific Objectives

1. To model a typical farming system in the Vaquerias region of Northern México in order to better understand the household, its decision making process, and the effects of the external environment on farmer risk.
2. To evaluate alternative crop management practices that could potentially increase farmer profits and reduce risks.
3. To explore methods of using the models and results derived from them to co-learn, with farmers, how to improve management decisions and provide decision aids.
4. To compare farmers' decisions with model results on field and farm scales.

Methodology

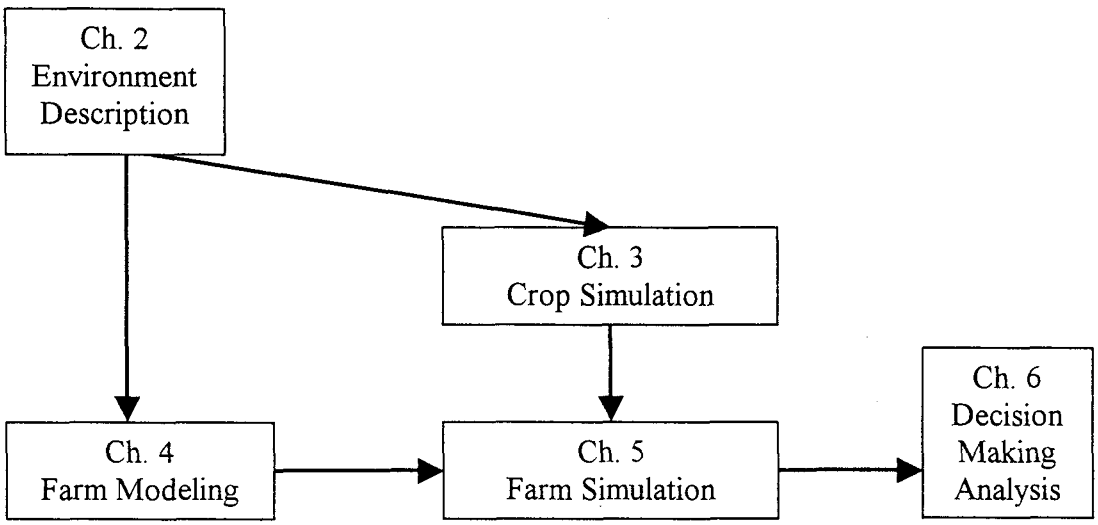
The study consists of five stages:

1. Site and management environment
2. Farm modeling
3. Crop simulation
4. Farm simulation
5. Farmers' decision making analysis

The general procedure is to construct a linear programming (LP) model that represents a typical farming systems; to simulate different scenarios by using inputs from crop simulation results; and to use these scenarios to compare farmers responses in order to learn about their decision making criteria.

In order to achieve the objectives, one chapter is dedicated to each one of the methodology stages, as it is shown in figure 1-2.

Figure 1-2. Methodology and dissertation chapters relationship.



Site and management environment

The site selected for this study is called "Vaquerias," and it is located in the General Terán county, state of Nuevo Leon, at the northern part of México. People from this site have experienced two projects trying to adapt themselves to the new circumstances.

A general description of the site's zone and in particular of the studied site itself, will be done from both secondary sources and data obtained in situ, by sampling, *sondeo* (P. E. Hildebrand, 1981a) and Local people's stories and experiencies.

Farm modeling

From data obtained by surveys, through oriented interviews that include an activity profile with producers and their families, a linear programming (LP) model will be developed to represent the livelihood strategies of the typical farm based household.

Crop simulation

Crops produced by householders will be simulated by using Crop Growth Simulation Models and the minimum set of data of the studied area, that includes soil, weather and cultivar's data. Nowadays, sorghum is the commercial crop, and maize is the one for the family consumption; the CERES (Crop–Environment REsource Synthesis) (C. A. A. J. R. K. Jones, 1986) crop simulation model will be used to simulate them. Also, dry bean and soybean, crops cultivated in earlier times, will be simulated with SOYGRO (K. J. Boote, J.W. Jones, G. Hoogenboom, and N.B. Pickering, 1998) and BEANGRO (G. Hoogenboom, J.W. Jones, and K. J. Boote., 1992; , 1994) simulation models. All models will be run through the DSSAT (G. Y. Tsuji, G. Uehara, and S. Balas, 1994) platform. These simulations will provide inputs to create various scenarios on the LP farm model, including crops performance, yield and resources.

Farm simulation

Real costs, including their variations, are important and necessary to the performance and evaluation of the model. Due to the possible case that maximum yield – in terms of the crop model simulation result – can be achieved from a resources allocation decision different from that of the one generating maximum economic benefit (defined as the difference between benefits and costs), input prices won't be simulated, but instead will be registered from the actual market.

Farmers' decision-making analysis

Once realistic scenarios have been created, farmers will be asked to consider them through questionnaires, surveys, and personal conversations. Questionnaires will be developed to test variables found in the hypotheses and research questions, as well as to take previous works into account (M. R. Campbell & A. Dinar, 1993). The analysis of results will seek to identify those main factors that farmers use as principal criteria for their decisions (R. A. Johnson & W. D. W., 1992). Discussion will consider previous contributions and concerns such as those of Olmer (1998) and Walker (B. Olmer et al., 1998; D. H. Walker, 2002).

Results

The expected results from this work include, for the studied region:

a) The description of the current decision making environment. This takes special importance after the experience lived by the ejidatarios - at that time - during the so-called Vaquerías Project.

b) The simulation's results of viable crop cultivars. To manage which will be necessary to obtain important intermediate results, as the genetic coefficients of some of these Mexican cultivars.

c) A model of ethnographic linear programming (ELP) which represents the farms. This farm model will be the model of the farms in the region.

d) A crop rotation proposal that maximize the family annual income. More than the sequence itself, the importance is based on the combined use of models that simulate the crop growth and the model that simulates the behavior of the farm: crop model and farm model working together.

e) Identification of the criteria that guide the decision making process of these ex-ejidatarios, which now are owner-managers of small farms of the Northeastern of México.

CHAPTER 2

CHARACTERIZING THE FARMING SYSTEM ENVIRONMENT OF NORTHEASTERN MEXICO

Introduction

The study area is a former ejido, one of the thousands that used to be in Mexico. It is located in the southern part of the Great Plain of North America, which starts in the Northeast region of Mexico, and it has a great history of survival and development attempts.

Mexico, like many other developing countries, has formulated and applied several different agrotechnology approaches to increase agricultural production and promote rural development. However most of them have failed due to their inability to meet the needs and interests of the people involved.

During the last three government periods (6 years each), a new political position has emerged related to ways in which to achieve rural sector modernization and how this rural sector can participate in the global economy and modernization. A new model was formulated and implemented under an agreement between government, private capital and Mexican peasants called ejidatarios.

This model, new for Mexico, was supposed to increase the production level at the field scale, and also improve the peasants' standard of living. It was implanted in 1990 in the General Teran county, state of Nuevo Leon, under the name of "Vaquerias Project".

Due to the importance of this project as the first Mexican case with high private participation with ejidatarios and government, this chapter will describe not only the regional characteristics, but also a brief history of rural development in Mexico, and the general situation of Mexican farms in this region.

Production conditions in the state of Nuevo Leon will be described first , as a base to start understanding the farming situation. Second, an overview of some main models and approaches for rural development will be presented, as a reminder, that helps to observe the project's approach in perspective. Finally, the general approach used at the Vaquerias Project is discussed along with ejidatarios' expectations based on a survey made when the project began.

Objective

The objective of this chapter is to review information that allows the reader to better understand the decision-making environment of former ejidatarios in the Northeast of Mexico.

Literature review

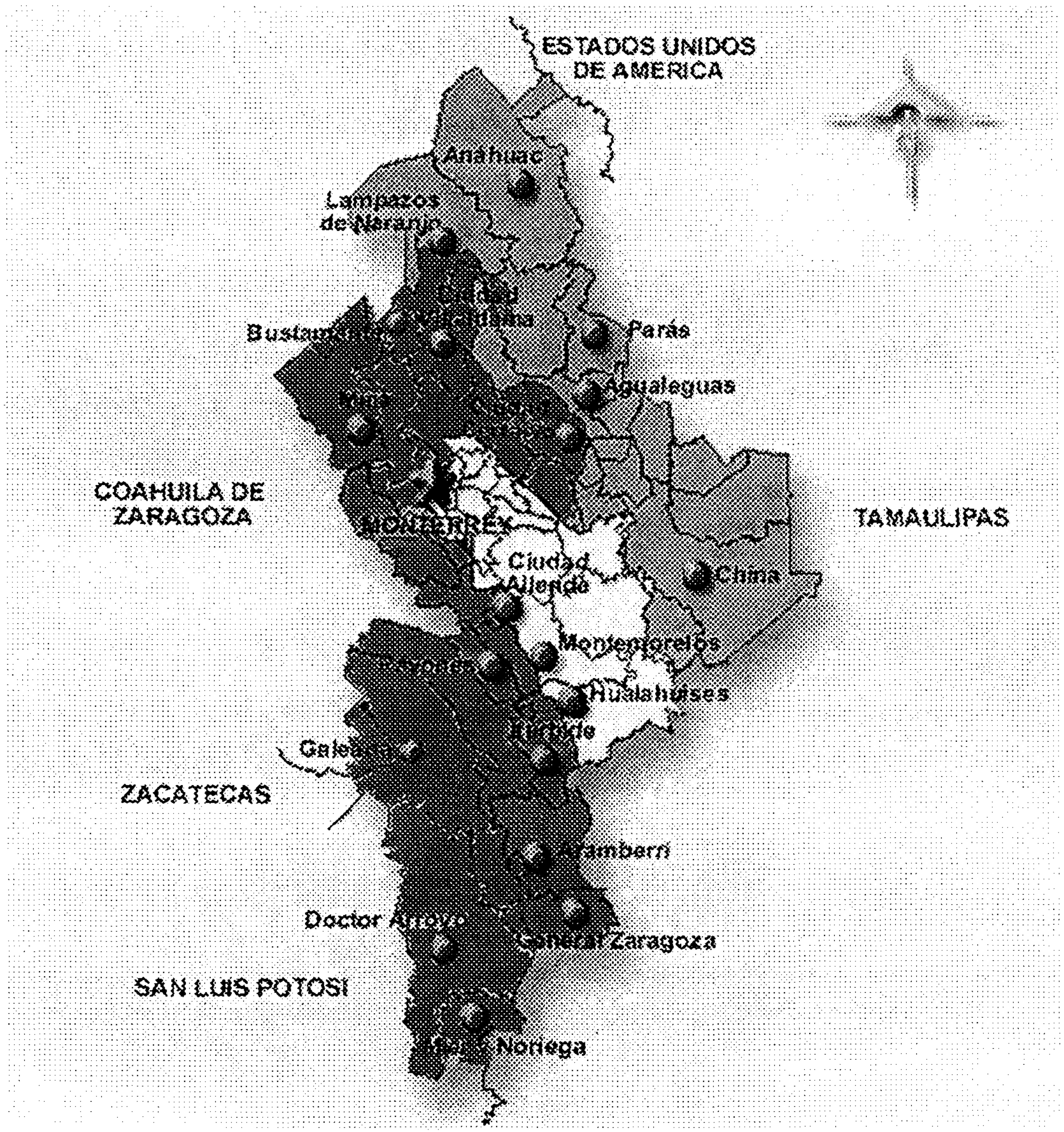
General Description of the Agricultural Conditions in the Region (State of Nuevo Leon)

Location of the productive area.

Nuevo Leon is a state of Mexico that borders with Texas through the Rio Grande River. It has approximately 4.5 millions of hectares considered suitable for some kind of agricultural activity. That productive area is located between 98°17' and 101° 7' west longitude and 23° 6' and 27° 50' north latitude. (Inegi, 2000, , 2003a).

Three main provinces shape the state: Sierra Madre Oriental (East Main Mountain Chain); Llanura Costera del Golfo Norte (Plains of the North Gulf) and the Gran Llanura de Norteamérica (Great Plains of North America). Figure 2-1 depicts these three provinces.

Figure 2-1 Three main oragraphic provinces of Nuevo León.



The first one covers almost half of the state and includes the mountains that make agricultural activities difficult. However, its valleys and hills support potato and apple production as well as cattle and goats. An old report (SPP, 1981) says that it is possible to support up to 400,000 hectares of agricultural production in this province; actually less than half of this area is currently used for agriculture.

The second one (Plains of the North Gulf) covers around 15% of the state land, and it is the most productive zone with high amount and quality of citrus products. There are around 230,000 hectares cultivated of different crops.

Finally, the last one has the remaining 35% of the state territory and it has the largest amount of land suitable for agricultural activities.

Climate Conditions.

Precipitation.

Water is the obvious limiting factor for agricultural development at this region. Annual average precipitation varies from 250 to 1000 mm, with highs during June and September. Most of the state receives between 350 and 600 mm of rainfall. The citrus zone has the highest precipitation and the south of the state the lowest.(CNA, 2003; INEGI, 2003a)

Temperature.

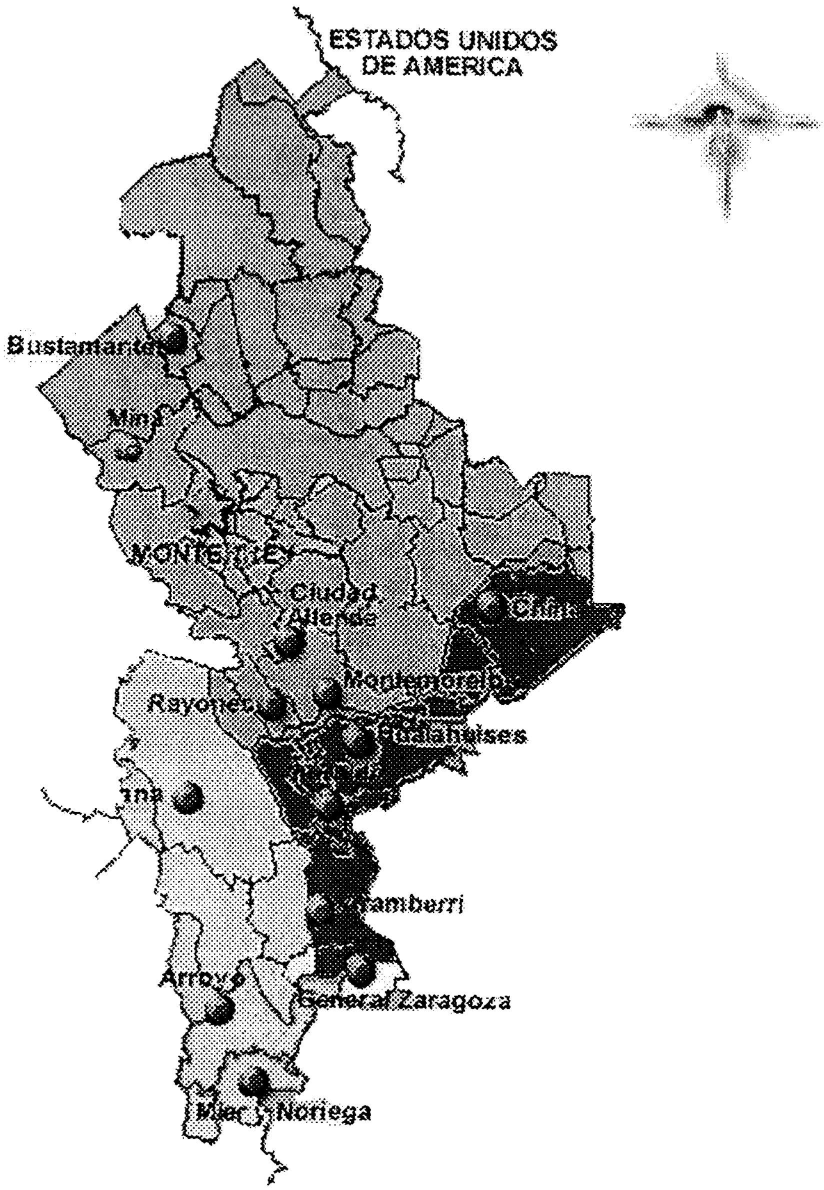
The range of the average annual temperature varies from 13 to 24 centigrade depending on the location in the state. However, the mean monthly temperature varies from 7.5 to 33° and the extreme daily goes from –5 to 45 Celsius centigrade. July and August are the warmest months, while December and January are the coldest (INEGI, 2003a; SMN, 2003). Freeze events cause loses to agriculture in this region. Freezing temperatures occur during 0 to 20 days each year in December and January.

Water and Land Uses

Possibilities to increase agricultural production and area are limited because of the lack of water. The state has four main dams with a capacity of more than 1600 millions of cubic meters of water. However, much of that water must to be used for human and industrial consumption. Several minor local dams serve agricultural uses.

All water streams and their watersheds are included in one of the four main regions, corresponding to bigger watersheds. Each of these regions in the state along with their watersheds, and the percentage of the land they represent are shown in figure 2-2 and detailed in table 2-1.

Figure 2-2 The four main watersheds of the Nuevo Leon State.



Source: **INEGI**. Carta Hidrológica de Aguas Superficiales (Inegi, 2003a)

Table 2-1 Hydrological Regions and Watershed of the State of Nuevo Leon

Region	Watershed	% of the State's land
Bravo-Conchos	R. Bravo-Matamoros-Reynosa	1.72
	R. Bravo-San Juan	32.91
	R. Bravo-Sosa	5.76
	P. Falcón-R. Salado	20.63
	R. Bravo-Nuevo Laredo	2.64
San Fernando-Soto La Marina	R. Soto La Marina	4.02
	R. San Fernando	13.40
Pánuco	R. Tamesí	0.74
El Salado	Sierra Madre Oriental	12.58
	Matehuala	0.38
	P. San José-Los Pilares y Otras	0.44
	Sierra Madre	4.78

Source: **INEGI**. Carta Hidrológica de Aguas Superficiales (NEGI, 2003a)

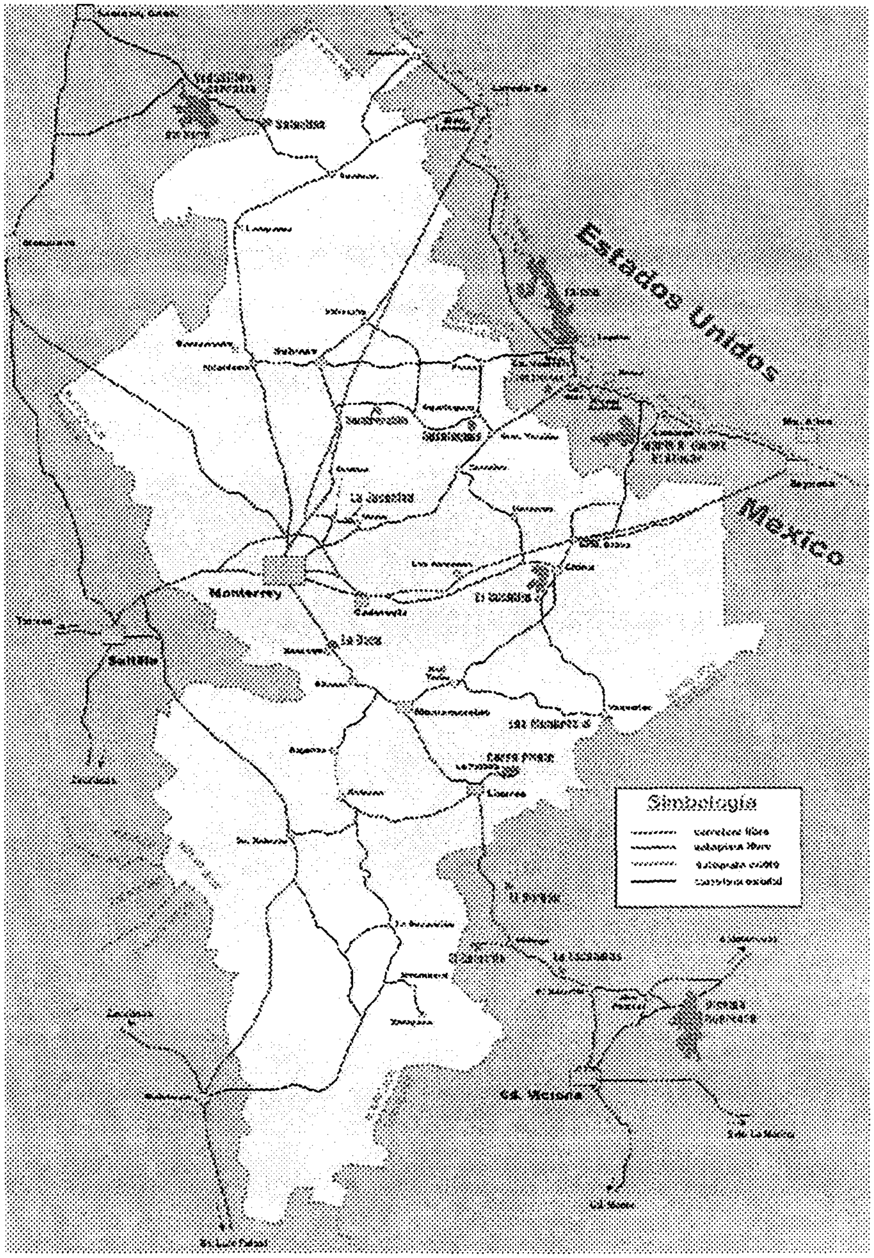
Table 2-2 Hydrological Regions and Watershed of the State of Nuevo Leon

Watershed	Bodies of water
R. Bravo-Sosa	Presa Agualeguas
	Presa Sombreretillo
	Presa Loma Larga
R. Bravo-San Juan	Presa El Cuchillo
	Presa La Boca (Rodrigo Gómez)
	Lago Salinillas
R. San Fernando	Presa Cerro Prieto (José López Portillo)
	Presa El Porvenir
	Presa Los Mimbres

Source: **INEGI**. Carta Hidrológica de Aguas Superficiales (Inegi, 2003a)

Several bodies of water, as natural lakes and dams, form the hydrologic structure for irrigation purpose. Some of those bodies are listed in the table 2-2 and shown in figure 2-3.

Figure 2-3. Dams and other bodies of water in Nuevo Leon State



The State's government reported that the agricultural productive area is mainly used for livestock production. Agricultural land use is shown in table 2-3. Animal production includes meat cattle and dairy cattle, as well as meat and milk from goats, meat from pork, poultry and eggs.

Table 2-3. Nuevo Leon agricultural land use.

TOTAL	6,455,500	
Livestock	5,535,938	
Irrigated grassland		18,470
Non irrigated grassland		527,167
Non cultivated pasture		4,990,301
Crop production	392,415	
Irrigated		130,492
No irrigated		261,923
Forestry	376,514	
Other uses	150,633	

Source: Data from state's 2001 report (Sfda, 2001).

Agricultural Production.

The main agricultural products from the state are citrus, sorghum, maize, pasture, beans, and wheat. With the exception of citrus fruits, all the other production is sold in the state, mostly for local consumption. Table 2-4 shows the latest available statistics about production.

Table 2.4 Nuevo Leon 2001 agricultural production. GR = grain FR = forage

CROPS	AREA HS	VOLUME TONS	VALUE MILES USD
ANNUAL			
WHEAT	21,614	52,923	5,946.00
MAIZE GR	44,969	32,549	4,509.90
SORGHUM GR	25,645	56,651	5,505.00
BEAN	4,719	1,826	1,301.40
POTATO	3,901	130,035	70,677.80
SORGHUM FR	26,732	104,109	8,770.70
MAIZE FR	23,052	37,047	4,475.50
OATS FR	2,341	20,555	2,075.60
OTHERS	14,334	76,955	26,258.00
TOTAL	167,307	512,650	129,520
PERENNIAL			
GRASS	132,895.60	802,354.40	70,803.092
CITRUS	29,142.03	423,754.25	33,303.149
PECAN	4,103.50	3,252.95	6,149.843
APPLE	2,210.00	10,369.30	2,567.332
LUCERNE	2,728.50	34,431.00	4,128.396
AVOCADO	751.00	4,257.50	2,741.100
OTHERS	1,435.00	6,495.61	2,333.998
TOTAL	173,266	1,284,915	122,027

Source: SAGARPA, delegación N.L. (Sagarpa, 2002)

Average crop yields are below national means and, in general, agricultural economy has a lower participation in the state economy. The state is known for its strong industrial activities. Although the state has the second high Gross Internal Product per capita in the country (Inegi, 2003c), participation in agricultural activities (including forestry and fishing) is around 1.5% (calculated from (Inegi, 2003c). The same can be said about availability of work, since the state reports less than 2% open unemployment, but it has been calculated up to 34% for rural area (B. Garay Valencia, 1990). Obviously, this situation is related to both the production intended just for self-consumption (not commercial), and the migration from the fields to the cities. Table 2-5 shows urban and rural population in several years, in a way that it is possible to note interesting population changes. Rural population is not only decreasing its percentage of the total state population, but also its absolute numbers since 1980. Both the high increase in urban areas and the decrease in rural areas are consequences of migration.

TABLE 2-5. URBAN AND RURAL POPULATION

YEAR	**TOTAL**	**URBAN**	**RURAL**	**% URBAN**	**% RURAL**
1930	417,491	172,175	245,316	41.2	58.8
1940	541,147	237,725	303,422	43.9	56.1
1950	740,191	413,911	326,260	55.9	44.1
1960	1,076,846	759,061	319,787	70.5	29.7
1970	1,694,689	1,296,843	397,846	76.5	23.5
1980	2,513,039	2,197,263	315,756	87.4	12.6
1990	3,086,466	2,889,317	284,263	93.6	9.2
2000	3,834,141	3,581,371	252,770	93.4	6.6

Source: Censo 2000 (Inegi, 2001)

The Ejido.

As consequence of the Mexican Revolution (1910) and based on the constitutional rules of the Great Letter (Constitution) of 1917, agrarian reform in Mexico gave origin to, and defined, three types of agrarian developments: the small property (private), the communal property (special for Indian settlements), and the common land called "**ejido**" (V. Manzanilla-Schaffer, 1976). This way the **ejido** system was initiated with a minimal extension of land given to each group of peasants. The rate was 10 hectares for each peaseant (now called ejidatario) or its equivalent, according to the region's productive potential. (Inegi, 1990).

Several definitions of ejido exist, related to its characteristics and its functions in Mexican agriculture. Many of the definitions refer more to the revolutionary feeling of social participation than to an organization for production. Like Aguirre (J. Aguirre-Avellaneda, 1976), who says that the concept of ejido must be referred as a form of social property of the economic resources. That "social property" is not a real property due ejidatarios can use (to usufruct) the land but not to possess it. This form of "property" is characterized by the interdependence that socialize the processes of production, interchange and distribution of the product. Its essential functions are to facilitate the democratic participation of the ejidatarios and to form the social subsystem of the agrarian reform, as one of the fundamental elements of the Mexican governmental system.

Probably those ideas and definitions were well meant, but they resulted in more political than practical implications. The hypothesis that land reform has spurred the expansion of agriculture has been widely supported by past governments. According to Martínez-Hernández (1992), "the central argument of these, is that land reform replaces a monopolistic structure with a competitive one, thereby producing the following benefits: expansion of cultivated area, growth of employment, increases in productivity and the general improvement of the peasantry's welfare. The empirical evidence, however, did not provide conclusive proofs that linked land reform to these benefits." (R. Martínez-Hernández, 1992)

In reality, decisions on production and functioning of the common lands have been regulated indirectly by the State, across the administrative organs of the common lands. These common lands, called ejidos, have enjoyed the protection and institutional support of the government as for credit assistance, inputs, organization and marketing of the products (with price guarantees). Legally, the production and agrarian allotment must be done collectively, but in practice these have been worked, in many cases, as very small independent holdings (S. Eckstein, 1966). Since 1990, it was thought that the legal aspects of the functioning of the ejido impeded the potential for agricultural development (R. Ramos-Oranday, 1990).

Two principal issues must be outlined with regard to the common lands: The ejidatarios are not owners of their land and their organizational system is used for political purposes. The rights of land use are nontransferable and the land cannot be sold, hired, or mortgaged. It is known that there always have been sales of ejido land use rights and declarations of private property in the common lands (S. Eckstein, 1966; R. Ramos-Oranday, 1990); however, this was infrequent and it was illegal. Due to the fact that ejidatarios are not-owners, they have the feeling (or the "need") of working for others, that remained from before the agrarian revolution, when they worked for the big landowners (S. K. Jarnagin, 1998).

About the political use of the system, it has been shown (L. González-Martínez, 1996) that the state (during the period of past governments) distributed resources in return for political support and legitimacy from the rural populace. By allocating resources, the state also guaranteed the participation of the peasantry in national agricultural programs.

In the state of Nuevo León, 609 ejidos were last reported to exist in 1991, with a surface of 2,203,522 hectares and 34,263 ejidatarios (head of household) (Inegi, 2003b). This makes an average of 64 hectares per household, from which around 10 hectares are suitable for crop production, and the rest is scrubland.

The small property is limited legally and is considered a social function. Legislation limits the agricultural land to 100 hectares maximum per family if it is irrigated or 200 hectares if it is non-irrigated. The suitable agricultural land in private hands is approximately 60 % of the available surface in the state. The maximum surface of scrubland in small property, used for grassland, it is decided according to the "index of grassland" that allows up to 500 heads of livestock graze, in conformity with the quality of the pastureland (Inegi, 1990). This means that semi-desert properties at North of the country have larger extensions for the livestock to graze than the tropical ones at Southeastern regions.

Institutional Support.

The main supports that the government has given to the ejidatarios can be grouped into few categories: credits, assurance, seed, irrigation, technical assistance and commercialization. The first two were implemented by the Bank of Rural Credit (Banrural); the seed, produced by the National Company of Seeds (PRONASE), also often was administered by Banrural. Technical assistance was offered directly by technical personnel of the Department of Agriculture; while the marketing, principally for basic grains, was done across the state company CONASUPO.

In the past, Nuevo León has had more than half of the agricultural land reported as damaged; like in 1987, when 77 % of the surface asked for insurance refund (INEGI 1990). This overuse was common because of the weather conditions, destroying the use of the agricultural insurance.

Rural Development

Conceptualization.

Elaborating a concept of rural development that contains all the elements generally accepted as indicators of development in the field and that is universally recognized, is not simple. Still in the major literature on rural development, most authors express their ideas around the analysis of factors that influence and limit rural activity and the well-being of the agricultural worker. (J. E. Araujo, 1974; H. Rosado, 1973; H. Southworth & B. Johnston, 1970; J. Velez-Hernández, 1977; M. Yudelman, 1970).

The World Bank had defined rural development in 1975 as "a strategy designed to improve the economic and social life of a specific group of people; the rural poor. It involves extending the benefit of development to the poorest among those who seek livelihood in the rural areas" (World Bank, 1975 cited by Gnagne, (2002). Rural development is also defined as a strategy to enable a specific group of people, poor rural women and men, to gain (or earn)for themselves and their children more of what they want and need. The group includes small-scale farmers, tenants and the landless (T. World Bank Group, 2003).

Miller (1985) synthesizes rural development in terms of the **self-determination** of the peasant. If the peasant can **perceive** that alternatives exist to his current condition, if he can understand these alternatives and select a realistic one and, if he can acquire the necessary power to implement his decision, then he will be involved in a process of sustainable development. Gagne (2002) also dares to say: "The definition of rural development for the 80 percent of the population in rural areas is access to basic human needs: health care, clean drinking water and nutritious food if possible".

But would there be development if that access has to be given as a gift each time that it is required? Rural development programs should enhance the ability of rural communities to develop, to grow, and to improve their **quality of life**. Unfortunately, most of them are limited to the financial and technical resources access, without taking into account the complexity about the peasants' **participation** and their learning in the process of **decision-making** thinking. "The strategy is doomed to fail if there is no clear understanding and knowledge of the people involved." (J. A. Gnagne, 2002).

As of 2003, the web site of the World Bank declares "The Bank's approach to rural development is holistic and multi-sectoral, focused on improving the well-being of rural people by building their productive, social, and environmental assets." (The World Bank Group, 2003).

Planning for Rural Development

Objectives and Goals

Plans and programs have to focus on the goals that they are intended to reach. DeWit (1988) mentions that, in order to have efficiency in planning, it is necessary to answer a series of questions. The answers to these questions do not depend only on the technical potential of the region, but also on the goals of development. Thus planning will be subordinated by the model of development and the strategy implemented by the governments.

Production and its limitations.

In the majority of the developing countries, with scant resources and food needs for a population that is rapidly increasing, planning is translated into programs to step up agricultural production. Hereby, the planning centers in those elements that determine such an increment. Because of that reason, Saravia (1985) says that governments try to stimulate the growth of production across the implementation of diverse political actions. The response of such actions is expressed by an increase in production caused by an increase in agricultural area, or an increase in the unit yields, or a combination of both. Anyone that selects alternatives will need land, a means of production, labor for work and suitable technology. Whereas Flores (1980) indicates that the essence of the problem is to identify those factors that limit generally the growth of production and to define the combination of inputs that offer high yields in increasing conditions of production and agricultural productivity.

Human Elements.

A different, wider vision and not limited to the crop's yields, it is the one that considers the human aspect. Dube, mentioned by Weitz (1986), indicated in the Rehovoth's second conference in Israel, that many technologically correct agricultural development projects could not produce notable results because they did not have a basic appraisal of the previous non economic conditions and did not take into account the human factor. In the same conference, Jewera, mentioned also by Weitz (1986) summarized the importance of the above, by saying that one speaks about the farmers being limited by tradition but that also planners are equally limited by tradition. Notwithstanding the fact that this has been said 40 years ago, some current programs, in the developing countries, are still making the same mistake.

Mosher, cited by Mosemen (1974), identifies some essential elements in agricultural development. Among those, he mentions the need of markets for products, and incentives for production; as well as education for development, credit for production, and the farmers' action as a whole.

Based on the previous ideas, one can affirm that the viability of a rural development project will depend on the conditions where it is to be applied, and of the good knowledge of the aspirations and social conditions of the benefited population.

Regional and Hierarchical Planning.

Due to diverse interests of the governments, often it has been suggested to select areas on the basis of their potentials and focus the limited resources on them (E. Flores, 1980). The implementation of this practice assures resources in the areas with more possibilities of success, but it again leaves the most helpless people out of development.

Regional development programs use this strategy of "zoning and support for infrastructure". This strategy is about increasing the physical infrastructure and the institutional presence, by means of contribution of financial resources and necessary personnel to facilitate the profitable production. Programs of regional development do not try to compromise the government in the productive process, but they create the necessary conditions in order that the producers can increase their crops' yields and their cash income (D. Barkin, 1978). Miller(1985) calls this an top-to-down or top down approach.

Somehow, regional development avoids the widespread application of strategies and recommendations, at the time that it helps to create a frame for rural development. Nevertheless, it could be convenient to consider the system hierarchy, since between the field and regional levels there is a wide space without attention. Among others, in this space exist the farm household-level, and the community-level. Both of them could have a strong influence on the farmers' decisions about the way of being involved with development projects, and the possible acceptance or rejection of governmental action plans.

Integral Planning

A more recent strategy in planning for development is the approach of the rural integral development. Weitz (1986) proposes a joint development of the secondary (manufacturing) and tertiary (services) sectors with the active participation of the population, considering people as the principal and most important resource.

> "The proposed strategy is based on three fundamental premises: first, the growth of the agricultural sector is the key for rural development; second, the development of agriculture demands a concomitant development of the secondary sector and the tertiary

sector; third, the social forces fulfill an important role in agricultural development." (R. Weitz, 1986)

Historical Models in Rural Development Planning

General Model for Rural Development.

This model includes all the theories that conform to the classic model of agricultural development in which, the agricultural sector is thought to be of vital importance for the growth and takeoff of the economies that base their development on the industrial growth.

According to this model, the role of agriculture is of providing the food, workforce and capital resources to the industry and the services. This is the reason why agriculture must modernize in order to stop being an obstacle to more general development.

The general model has its foundation in the classic and neoclassic conception of development, and it can be expressed by approaches that interpret in different ways the role of the agricultural sector. According to Hayami and Ruttan (1971), some of these approaches are: the Traditional German Approach represented by the works of Karl Marx and Friedrich List; the Structuralist Approach, presented by Fisher and

Clark; the Approach of Development by Phases, based on the works of Rostow, Perkins, Wítt and Johnston, and others.; the Approach of the Dynamical Dualism, supported by Ranis and Fei and created for a closed economy; and the Approach of the Dualism of Enclave, shared by several Latin-American authors and defended by Higgins and Mint.

The approach of dualism can be analyzed at the level of countries. Mellor and Adams (1986) mention that

> " ... we live in a paradoxical world. In the developed countries of Europe, Australia and The United States, the food surplus continues being increased reaching records. In these countries, the agricultural production is frequently subsidized by the State, and the farmers are often paid in order that they do not produce any more food. Nevertheless, in the developing countries of Africa, Asia and Latin America, the situation is completely different. In these countries, the food deficit - not surpluses - are the topic in consideration, and the farmers work often under the load of high effective rates of tax and low levels of assistance services from both the public and private sectors."

Technological models and of Productive Increase

Model of Diffusion and Generation of Technology

Based on the theoretical concepts of the general model, several models have been developed focusing on the generation and diffusion of new technologies to accelerate the development of agricultural production. The generation and technological diffusion refers basically to the use of inputs for high profitability, such as new cultivars, genetically improved seeds, use of fertilizers, pesticides, modern machinery, and others.

The generation of the new technology has been carried out in the more developed countries, in regions where the producers are innovators and of a business type, giving excellent results. The diffusion and use of this practices in underdeveloped countries has been very limited. Volke (1987) mentions that where the adoption of technology is integral and the farmers produce for the market, the model of generation and diffusion of technology is excellent, but he indicates that the situation is very different in countries with subsistence agriculture and farmers with different mentality from innovations and business.

One of the programs practiced in Mexico and that has followed the line of technological changes, is the Regional Program of Rural Development called "Plan Puebla", starting in 1967. The objective was to achieve rapid increases in yields of basic crops in non-irrigated areas, taking into account the local technology of production and on the basis of unlimited credit for adoption of the new technology. Volke (1987) mentions that, certainly, the yields were increased; nevertheless, fifteen years after its beginning, only 19.3 % of the farmers had adopted completely the technology. He assumes that situation was because of the lack of consideration of the farmers' participation in the whole process of development, and moreover, because the social and cultural aspects were ignored in the planning.

Barkin (1978) mentions another program with similar characteristics, the "Plan Chontalpa", also in Mexico. The goal was to serve as a model in the utilization of the great productive potential of the humid tropics and for the reorganization of the ejido system. From its beginning, it stumbled over difficulties in achieving its goals relative to production and the incorporation of the ejidatarios in productive management.

Organizational Models.

Examples of these models are cooperatives of agricultural production in Israel named Kibutz and Moshav. The cooperatives are organized under the modern concept of agricultural companies, and their objective is to raise to the maximum the crop's yields, and promote social cohesion among its members. The productive activity of cooperative's members is not limited to agriculture; they also develop rural industrial activities.

Volke (1987) proposed an organizational model based on the independent organization of farmers, focused on the solution of their problems and satisfaction of their needs as a social group. This model departs from the problems that subsistence farmers face; under this new concept of development, the producer is the center and real motivation for development. Miller (1985) qualifies this approach, as a model of "bottom-up" or "development by means of revolution", where the objectives and requirements are formulated by the peasant.

Example of this model mentioned by Volke (1987) is the organization called *Cooperativa Agrícola Regional Tosepan Titatanizke* (Agricultural Regional Cooperative society Tosepan Titatanizke) of Cuetzalán, Puebla, Mexico. At the end of 1984, this organization included 46 communities and more than 6225 members, and the central point of the development was defined by the organization and not the production increase. Volke (1987) indicates, nevertheless, that the plan has achieved increased yields similar to those of the Plan Puebla, but adoption of technology has been almost generalized.

Approach of Modernization - Co participation

This model appears as an alternative for the solution of the problems inherent in the rural Mexican development, which have continued latent for many decades (G. Gordillo De Anda, 1990). This approach was proposed by the Movimiento de Promoción Rural (Movement of Rural Promotion) at the end of the 1970s decade and it is based on the recognition that agricultural development in Mexico was in a deadlock and there was a very low standard of living of the Mexican peasant (P. Livas Cantú, 1978). The approach implies that the human element must be promoted by being involved in the development plan and actions. This would be achieved by means of joint participation with the State and the private initiative, focused on the development of agricultural projects according to the objectives of all involved.

The strategy adopted to raise productivity and development of the peasant; it is the conjoint participation in a partnership with the producers, the State and the private enterprise. According to this approach, productivity and social improvement would be achieved by means of modernization and development of economically viable projects for the involved partners, where the free, responsible and efficient participation would be the key element of success.

Methodology

Precedents: The Vaquerias Project

The joint approach of participation was practiced in 1990 in Nuevo León, Mexico, as part of the policies of modernization and conciliation adopted by the government, and the recognition of the need to create better conditions in the rural areas (G. Gordillo De Anda, 1990). In 1989 the government indicated that:

> "Mexico might not make its project of modernization effective on the base of a rural society without dynamics of growth, but especially, without a significant improvement in the quality of life." (C. Salinas De Gortari, 1990)

The approach was tested in what was called: *Plan de desarrollo rural Proyecto Vaquerías* (rural development plan Vaquerias Project). This project counted on the participation of the government, a large private company, and ejidatarios from three ejidos: San Juan de Vaquerías, Francisco I. Madero, and La Barreta, located in the General Terán and China counties, in the state of Nuevo León. The productive area of the project was approximately 5,000 hectares.

Scopes and Limitations of the Approach.

The approach of modernization - coparticipation contains elements that are identified with the models of adoption of technological innovations that stem from the general model of rural development. For example, it considers the use of modern technology and inputs for a high yield, a solution to the problem of the development (Y. Hayami & V. W. Ruttan, 1971; J. W. Mellor, 1970; T. W. Schultz, 1965; H. Southworth & B. Johnston, 1970). It also contains organizational elements that rest on the models experienced previously in some regions of Mexico (D. Barkin, 1978; V. Y. S.-G. Volke-Haller, I, 1987).

A new element of the approach and very transcendent in the future considerations of rural development, is the incorporation of the private initiative, organized in non-rural companies, in the objectives of modernization and with common interests in agricultural development.

It can be said that the model has the goal of capitalizing agriculture in joint form between the State and the private company, modernizing at the same time the organization of the productive activity, in order that the agricultural sector answers effectively to its role as supplier of prime matters and food. The peasant is an active element inside the organization and an agent of the change.

The approach, seen in this way, may represent a major change in the system of production related to the making of decisions like what to produce and how to produce it. It was hoped that the change of the organizational system and the capital reversion to the agricultural sector were generating a very favorable situation for production and productivity in the field.

Procedures

Oral stories, interviews and surveys were used to obtain the ejidatarios impressions about the project in 1990, when the project was just to begin, and in 2000, ten years later.

Surveys used in 1990 included 86 ejidatarios from around a total of 400 ejidatarios that lived in the three largest ejidos. That is the 21.5%. There were just permitted interviews of 22 ejidatarios between 2000 and 2002, out of 100 left (22%) of the main ejido, called "Vaquerías".

In both situations, samples were not random, but were opportunistic. Even when questions included personal and production data, our focus in this project was to determine over their perception about the project's possibilities of success.

Results

Expectations before the project (1990)

From the 86 ejidatarios in the early survey, 74 decided to join the project, 60 (80%) of them as associate member, the rest only as workers.

Even when some of them expected to rent their land in the future, expectations of the majority (77%) were to stay as partners of the project. 90% agreed with the organization and the way they plan to produce; just 40% would plant their own crops beside the project's ones.

Their expectations about increasing their living standard were really high: 96% expected to improve in general; more than half expected to increase cash income from 50 to 100%. They expected to receive training and education.

Interviews after the project finished (2000 – 2002)

Investments and contracts were made for 12 years. During that time, the project was supposed to be working well enough, to be able to give ejidatarios a solid base to keep the high level of work and production. Yet, the project finished after just 3 years.

Ejidatarios received about the same income as before the project, but it was by means of salary. They felt bad about their lack of participation on the decision-making process, and did not speak well about the association and the project administrators. However, most of them, would be an associate member on a similar project.

That decision of being part of a similar project, is mainly based –according to their own words- in two situation: a) As results of their experience in the Vaquerias project, they learned about association and gained some infrastructure like parts of an irrigation system. b) The huge changes in agricultural policy that left a situation different than before the project. One peasant summarized that now, they not only do not have the project, but neither have the Banrural for credit, nor the CONASUPO for marketing their crops, nor free technical assistance. He forgot to say, however, today they have their land.

Actually, what happened was a major constitutional change to make Mexican ejidatarios legally owners of their land, but also to close some state agricultural enterprises. Now ejidatarios are the same as most small-scale farmers. They own their land, over which they can and should make their own decisions.

Summary

As a manner of conclusion, it is possible to make a brief summary of the current situation as it is being affected by new proposals.

During the Mexican post-revolutionary period of legal land reform (1910-1991), government created policies that divided large areas of private land. According to Berra (1999), the policy of land distribution as an obligation of the state not only encouraged the creation of smallholdings and the fragmentation of land but allowed political control of the peasants.

Ejidatarios were not required to make decisions over the land they worked. This was due not only to the fact that they did not own the land, but the government made decisions through credit and market institutions.

In 1992, two major changes occurred: (1) modifications were made to Article 27 of the Mexican Constitution, privatizing the ejido land system and making farmers from ejidatarios and (2) Mexico ratified NAFTA, taking these new farmers into a global market.

Preciado (1999) explains that,

> "to comply with this mandate, the Federal State had to implement an ambitious land regularization program that included census of plots contained in ejidal structures and the provision of individual land certificates, communal land certificates, and a title for the Urban plots, as pertained for each case. This program initiated in 1993, and one of its conditions is that ejidatarios' participation would be voluntary. [...] The analysis revealed that PROCEDE is considered a beneficial program overall, especially as one that has strengthened land tenure security on the ejido units." PROCEDE is the name of the program.

Amendments to Article 27 of the Constitution, which were implemented in 1992 and began a new period of legal land reform in Mexico, did not result in a fast drop in land tenure on the social sector, as pessimistic critics of reform predicted, nor did it produce the massive investment of private capital announced by government sectors. Ejidatarios and communal landholders were undoubtedly benefited from the mere acquisition of land titles, and certificates of rights to communal land and parcels, making them eligible for credit. (R. V. Berra, 1999).

The Vaquerias project failed probably because it was not as integral and peasant-participatory as it could have been. Now, ejidatarios have a new situation, thus new schemes and different ways to help them to manage their very own new farms have to be found. It is the objective of this dissertation to contribute theoretical and pragmatic support toward this end.

CHAPTER 3

CHARACTERIZING EJIDO FARMS OF NORTHEASTERN MEXICO

Introduction

Chapter 2 described how the ejidatarios of Vaquerias lived with the major rural development effort in Mexico in recent years: the Vaquerias Project. After the project ended, the ejidatarios preserved some resources and had gained a good learning experience. However, in the next years, instead of continuing with the wheat and soybean rotation, they returned to planting sorghum, with which they achieved a record yield and said, "we are better alone."

However, in the following years they experienced a different situation. They lacked money to finance the work; the irrigation system was not maintained; the intake of the dam basin broke and the ejido was without water for irrigation. Without money and water, they were not comfortable in returning to the situation they had before the project, since they had experienced a higher income and higher expense levels.

Now the ejidatarios not only have received the assignment and property of their land, but they also have the offer of low-cost financing to renew their irrigation system, and repair the dam basin intake. They may also receive technical advising. Turned into owners, these new farmers make decisions to create their own proper farming system with current resources and experience from the past.

In this chapter, the current farming system is described in the ejido Vaquerias' community, including the characteristics of its household and livelihood options. A literature review provides us with an idea of the general characteristics of the area and of the tools used in this study. In the Methodology section are shown the instruments used, which helped to obtain the suitable description of the current farm system. The section of Results presents the farming system using a descriptive linear programming (LP) model.

Literature review

General Description of the Research Area

In chapter 2 was mentioned that the state is divided into three main provinces. The focus area of study is in the lower part of the province called the Great Plain of North America, at the East of the state of Nuevo Leon, inside the General Terán county, limited by the State of Tamaulipas. Geographic coordinates of the settlement are 25°08'20'' of north latitude and 99°03'13'' of west longitude. The strategic selection of this location as a case study, responds to the impact on agricultural development plans, agricultural research and extension services, and governmental policies that represent the test area for Constitutional changes, as part of the Vaquerias Project.

While settlement altitude is 160 m (meters above sea level), the agricultural area is mainly from 130 m to 150 m. Before agricultural practices were established, shrubs of different species of the *Prosopis* and *Acacia* genera dominated the natural vegetation. Climate is subtropical-sub humid with scanty rains.

Soils of the Area

Landscape of the area is quite uniform containing plains and soft hills. Principal soils are Xerosol (Aridisol) and Vertisol with sedimentary and alluvial soils on almost the whole surface area. According to the report of Soil Types of the Vaquerias Project (C. Ortiz Solorio, A. Nolasco Sanchez, & M. Ibarra, 1993) there were 7 different types of soils in the project area. The area corresponding to the ejido Vaquerias has three types: White soil, Black soil and Yellow soil.

The white soil makes up 55% of the area. This soil is characterized by its clear color, due to the high content of calcium carbonate ($CaCO_3$) (more than 40%); its low values of Cation Exchange; and the high presence of carbonate residues or shells. Most of the white soils at Vaquerias do not have salinity problems. The profile of this soil is 100 cm deep, with three well-marked layers: 0-30, 30-70, and 70-100 cm.

The black soil constitutes the 50% of the area. It has a high clay percent, and a non-relevant quantity of salt. Ejidatarios call this to be a "good land", because it is considered a productive one. Its profile is more than 1 m deep, and shows five layers down to 120 or 150 cm in depth.

Yellow soil comprises just 5% of the irrigated area. It is clear brown because of the $CaCO_3$ that it contains. Its characteristics are low clay content, and low Cation Exchange Capacity values. All types of soils have sufficient natural drainage for crops. With the exemption of yellow soil, which is an Entisol (Typical Ustorthents), the other two are Aridisols (Ustollic Calciorthids the white soil, and Vertic Haplargids, the black one).

Irrigation

During the last few decades, the State government has dedicated part of its budget to help in the construction of dams for agricultural uses. In addition, maintenance of the dam, the intake channel, and the irrigation canal are paid by the state government. One of those dams was made 5 kilometers from the ejido Vaquerias, to serve as surface furrow irrigation on three ejidos and other settlements, with a canal that reached almost 5,000 hectares. This dam is known as Los Mimbres (The Wickers) dam, with a capacity of 30 million cubic meters, and it is used not only for irrigation but also for sport fishing and recreation.

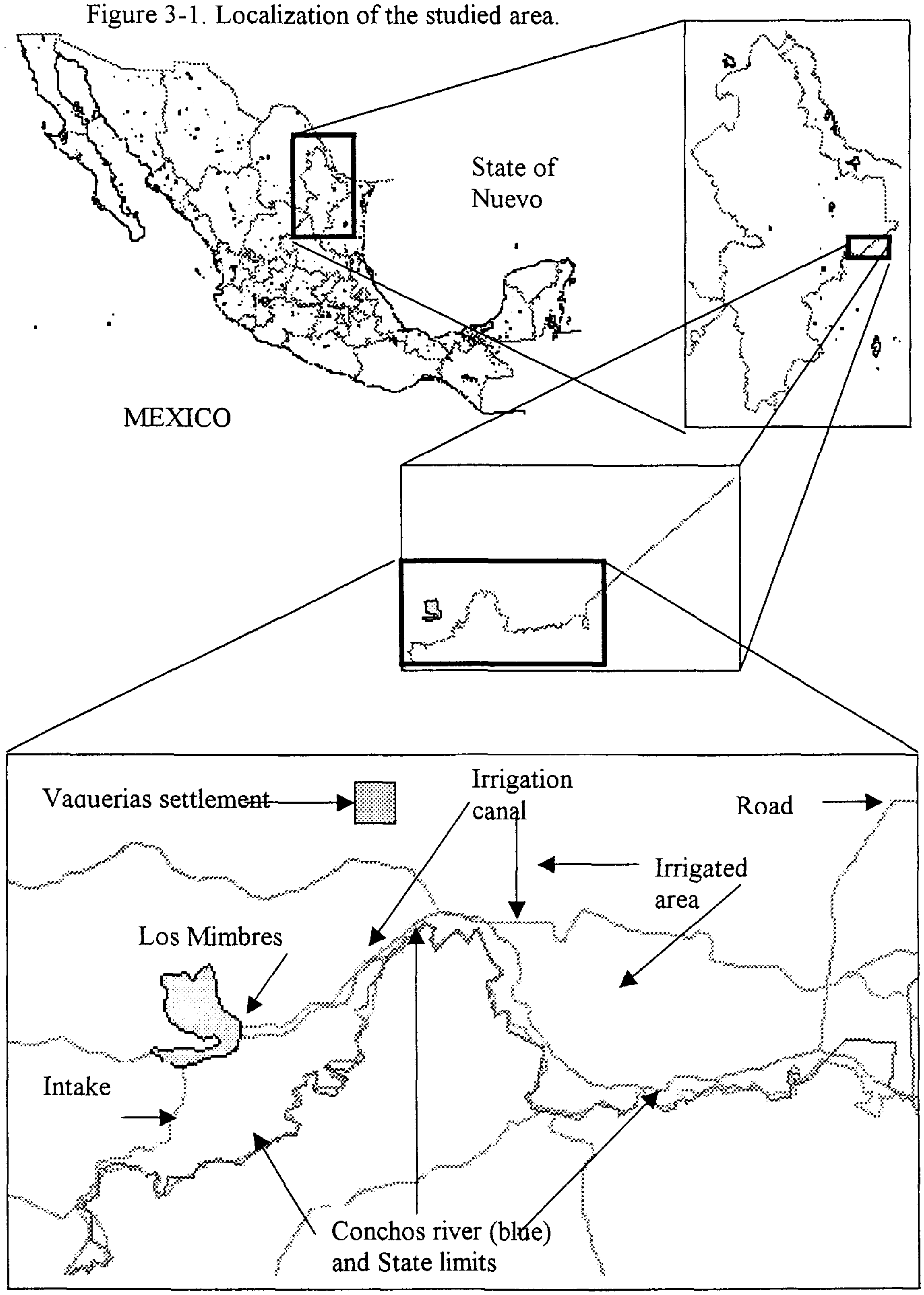
Los Mimbres takes water from the Conchos River 5 kilometers up fromits main basin. The Conchos River marks the frontier between the States of Nuevo Leon and Tamaulipas, and belongs to the San Fernando River watershed. Water from Los Mimbres, goes across the irrigation area through the canal down to join the Conchos river again; several kilometers ahead, in the State of Tamaulipas, will join the San Fernando river to flow towards the Gulf of Mexico. Figure 3-1 depicts these water structures and the localization of the studied area.

During the Vaquerias Project (1990-1994) investments were made to change the gravity irrigation to cover the almost 5,000 hectares with new side-roll irrigation equipment. That was used while the project worked and one more year, but it was then abandoned because of the lack of water.

The livelihood system

With the exception of newspaper journal articles about political events, nothing about the livelihood system has been published, currently this work is being written. Two anthropologists from the National Institute of Anthropology and History (INAH) have been working in the zone and we expect to be able to read their report before the conclusion of this dissertation research. Meanwhile, we hope

Figure 3-1. Localization of the studied area.



that this work helps to better understand what happens in this type of farms in Mexico and their production situation in this region of the country.

The approach used in this study was adapted from those proposed by Farm System Research and Extension (FSRE) and Sustainable Livelihood (SL). Since the 70s, Farm Systems studies created the concept of Farm System Research (FSR) and, consequently, the Farm System Research and Extension (FSRE) concept.

FSRE not only includes On-Farm's research concept, farmer's participation and "bottom-up" research plan and development, but also it owns them to the degree of considering them to be inherent and even synonymous.

The idea behind this, is that the agricultural research that is done with the intention of improving the standard of living in the rural area, will have a wide, positive and real effect. For this research needs to be relevant, in agreement with the needs and characteristics of the place and to have results that can be actually accepted and adopted by farmers. To achieve this it is suitable that research (or part of it) be realized on-farm, with farmer's participation, and based on the farmer's situation.

Both research relevancy and farmers' participation, require a series of tools to obtain the farmers' involvement and interest as well as information needed in the study. Among those tools, some are adequate for low budget and time constraints and, that also promotes better contact with people of the community. Some of these tools are: the sondeo, the short survey, the guided interview, and the case studies, among others.

Since a large part of the poverty and the underdevelopment of the world is in rural zones, it is hoped that theory of the rural development has relation with that of the agricultural development. From the same authors and concepts of systems that gave origin to the farming system concept and the widely accepted idea of the sustainable development comes the concept of sustainable rural livelihoods, and later just sustainable livelihoods (SL). The champions of this concept propose participation as the basic condition inherent to the SL concept and rely on the same tools that were used in FSRE. Some of the first ones that proposed and popularized these ideas include Norman (D. W. Norman, 1978), Hildebrand (P. E. Hildebrand, 1976, , 1981a, , 1981b, , 1982) and Collinson (M. Collinson, 1981), and others adopted and adapted them, including Chambers (R. Chambers, 1981), Conway (G. R. Conway, 1985, , 1987), Scoones (I. Scoones, 1991) and others in the area of Development. Appendix 1 shows a publication relationship between these SL and FSRE.

Linear Programming and Simulation Models

Linear Programming is a mathematical procedure developed in 1940s and broadly used as a powerful tool to help determine the optimal allocation of resources.

Through the years, LP has been widely used to simulate farms and different aspects of agricultural systems, especially to compare and evaluate alternatives on production technology, management, and policy. It is a very useful tool to test technology alternatives generated in the agricultural research national or international centers (J. P. A. Lamers & M. Bruentrup, 1996). Thompson (1995) used LP models to test proposed technology; by doing that, it was possible to use on-station research data with a farm-model approach. Stoorvogel (1995) used LP along with other models to evaluate alternative land use in Costa Rica, and an economic analysis of the agricultural cost of soil salinity was shown by Marshall and Jones (1997), using LP.

It is possible to use LP as a development planning tool not only for crop, but also for animal production (J. J. Glen & R. Tipper, 2001) from dairy cattle (S.

Ramsden, J. Gibbons, & P. Wilson, 1999; C. M. Yates & T. Rehman, 1998) to even aquaculture production systems (E. M. Wade & J. G. Fadel, 1997). LP models were also used to evaluate policy effects in the European Community (A. B. Donaldson, G. Flichman, & J. P. G. Webster, 1995; Topp C. F. E. & Mitchell M., 2003); and on the topics of on-farm research (D. J. Pannell, 1999), and sustainable development (P. Zander & H. Kachele, 1999).

In its efforts to provide scientific description of individual human societies, Ethnographic research uses methods in which there is a lot of contact with the people. Some examples of these high-contact methods are: IMMERSION, where the researcher becomes a member (or almost a member) of the community that he studies; community's PARTICIPATION in order to obtain data; direct OBSERVATION of the activities by the researcher, ON-GOING INFORMAL DIALOGUE with community members, and IN-DEPTH INTERVIEWS, among others, as different ways of obtaining relevant information.

Using ethnographic research methods (immersion, participation, observation, on-going informal dialogue, in-depth interviews, etc), Hildebrand (2002b; P. H. Thangata, P. E. Hildebrand, & C. H. Gladwin, 2002) proposed an adaptation of linear programming (LP), called Ethnographic Linear Programming (ELP) to develop models that take into account the human element of the system, that represent and describe actual farming systems, and that simulate the farmers' actual and possible strategies.

As for the ELP, developments and applications can be found in several works following the Hildebrand's orientation, as in Bellows et. al. at Costa Rica (B. C. Bellows, P. E. Hildebrand, & D. H. Hubbell, 1996), Cabrera at Peru (V. Cabrera, 1999), Bastidas at Ecuador (E. P. Bastidas, 2001), Kaya et. al. at Mali (B. Kaya, P. E. Hildebrand, & P. K. R. Nair, 2000), Merry et. al. at Bolivia (F. D. Merry, P. E. Hildebrand, P. Pattie, & D. R. Carter, 2002), Mudhara at Zimbabwe (M. Mudhara & P. E. Hildebrand, 2002), Thangata at Malawi (P. H. Thangata et al., 2002), and many others.

Objectives

The main goal of this chapter is to describe, through a model that represents them, the existing farming systems in the common land ejido Vaquerias, including the characterization of its household and the livelihood options they have. The first objective is to identify the characteristics of the livelihood, using ethnographic research methods. The second objective is the development of an Ethnographic

Linear Programming (ELP) model capable of mimic the behavior of the decisions made until now by the ejidatarios.

Methods

The general methodology followed the procedure for developing and using ELP models created by Hildebrand (2002a). In order to obtain the necessary data, ethnographic research Rapid Appraisal Methods, were used. Among these methods, this work used the sondeo, as explained by Hildebrand (1981a); oral stories; case studies, and on-site, in-depth interviews.

Livelihood description

Sondeo.

To learn about the livelihoods in the community, a team of two researchers held conversations with nine persons of the ejido. Although questions and points of interest were previously established in a questionnaire, there were no structured sessions of answering questions, but informal guided conversations. People for conversations were not previously selected, but were chosen on an opportunistic base. However, they included at least four of the community moral leaders. Previously, general information was obtained from secondary sources and from interviews with people related with Vaquerias Project in the past, and/or with Ejido Vaquerias' actual credit and market information. The sondeo was done during five days. As people started given us the same answers each time, we decided to stop. Answers were repetitive, and logically congruent with the same big picture. This procedure helped to draw a first draft of the model and to plan the following actions.

Survey.

A survey instrument was structured from three sources: 1) the sondeo's results, 2) a survey made in 1990 at the same region, and 3) a survey conducted by Cabrera (1999) in Peru with the purpose of identifying elements to describe livelihoods. The survey was applied by a 5-member team to 22 people, who were heads of their households in the Vaquerias ejido. Questions were asked about quantities related with the existing activities in the area (which were identified during the sondeo), such as quantities of different inputs needed for those activities (i.e., fertilizer, and time used); and quantities of production or yield obtained. Also, the survey included some qualitative questions, such as who does the work, and factors that determine the quality of life. Results from the survey were used to construct an initial basic linear programming matrix, to categorize some possible types of households, and to identify some possible farmers for in-depth interviews.

In-depth interviews

In-depth interviews were carried out in a sequential way on five households, asking and obtaining more detail as the next household was being defined. Similarities allowed making advances in model construction along with interviews.

Oral stories

Storytelling about the community and its passage through several situation (including political development plans), came during the three phases (sondeo, survey and in-depth interviews). Some of them enriched our gaining of information.

Specific household

Three main different ejidos participated in the "Vaquerias Project": Vaquerias, la Barreta and Madero. This research work is concentrated on the livelihood system of ejido Vaquerias only, the most receptive to work their land using modern technologies.

During the time of in-depth interviews, a linear programming matrix was developed, taking information of the two first households for the first matrix outline and using the last two households for validation. No household groups were formed because of the similarity of all households, at the time of the present work.

Results

Livelihood systems

Types of Livelihood Systems

No different livelihood systems were identified in the ejido Vaquerias while conducting the sondeo. It is important to remember that this community was formed to constitute an ejido, and it had been an ejido for several years. This explains why each household was practically the same to the other. That means, due same quantities and qualities of resources were distributed among people with similar ages and background, now they have the same quantity and quality of crop land, grass land, and house land; the same type, size and shape of house; and a very similar family structure. In other words, there is practically only one type of household at ejido Vaquerias... until now. There are three issues, however, that can make a difference from here after; these are the Vaquerias project, the PROCEDE legal action, and the destination place of emigration from the ejido.

The Vaquerias Project, explained in Chapter 2, provided the ejido with an experience that affected diverse aspects of ejido life in different ways. For example, on one hand, the project left infrastructure of irrigation, roads, crop machinery, a leveled joined field, and the knowledge to use all of them. This can help with wealth development of ejidatarios. On the other hand, the project encouraged people to adopt the habit of having and spending pocket money through the practice of weekly salary. This initiated people as members of the consumer society that welcomed them with the emerging bars, little stores, and frequent trips to the city.

PROCEDE (S. A. Preciado Jimenez, 1999) is the name that government gave to an action for giving the legal ownership of the land to the ejidatarios who had been working on it, enjoying just the usufruct, but without being owners. During the ejido system, ejidatarios could use the land for crop production, but they were not legally able to rent or sell the land. It has been stated that the idea of working on land that is not one's own land, keeps him or her with the feeling of being an employee (of the government, in case of ejidatarios). This situation discouraged investments on the land. This could explain in part the fact that a huge number of Mexican campesinos do not set a goal to increase production for the market, and they just aim to ensure their own family consumption.

PROCEDE came to the ejido Vaquerias years after the Vaquerias project failed and after some years without the irrigation system working adequately. Today, heads of households own their land and are able to get some financial credit to fix the irrigation system, work their land and even sell it rent it, or buy more.

During those years without irrigation, after the project failed and left the ejido, the community revived an old tradition of emigration to the cities and to the United States (USA). Some people at the ejido thought that some who left would come back when they saw the community progress. No one has come back until now, except for holidays. This part of the story has two opposite effects: a) If the emigrant is a household head, he can go with the complete family and look for a relative sharecropper, to rent, to lease, or even to sell his land, losing his rights and abandon the ejido. b) If the emigrant is a son (single or married) of another household head, he can send money back to his parents' house to help support it, bring it the opportunity to invest in their land and/or to buy more land, now that it is legally possible.

The combination of these three issues (the Vaquerias project, the PROCEDE legal action, and the destination place of emigration from the ejido) has established such a situation that, some of them are going to lose resources, while others are going to acquire them. Thus, a new study some years from today could show evidence of marked differences between types of household.

Yet, today, a meticulous examination can separate households by their members' age composition as young and old households, and those that have a female household head. However, even widows, who have land rights, have the same enterprise portfolio and almost the same resources as any other peasant in his household. It can be thought that family composition directly affects the quantity of food needed for minimum consumption (production that the household must assure), and the labor availability. Both things are correct, nevertheless, mechanization has done labor not a problem, and the minimum consumption is overcome by the today's farming system.

Household description

The household of the ejido Vaquerias is composed of families whose parents' age range between 35 and 60 years old for both, husbands and wives; most are in the 40s. The number of household members varies between four and five; that means just two or three children, which is low for the common idea of huge rural families. Children living at the ejido are of school ages, form 5 to 16 years old. Even when some stay after that age, most go to the cities to continue studies or to look for a "well-paid" job. Cities that they leave for are those of the state (Teran, Linares, Montemorelos or Monterrey) or the USA.

Parents have a formal education up to 4th grade of elementary school, while their sons and daughters reach the end of secondary (junior high) school. Parents have authority and control over household resources, with different tasks assigned. Those resources include the standard small house, with its courtyard (solar), 11 hectares for irrigated crop production, and 55 hectares of grassland.

Risk management

Agriculture is a risky business and household decision makers have to make decisions to minimize the risk of not having adequate food supply, clothes and a secure roof for his/her family. Weather variability, crop plagues and diseases, and low market prices, are common causes of risk in this region. In addition, the big picture (political, economical, and agricultural-supportive infrastructure) affects former risks; ejidatarios from Vaquerias have to work under a high level of uncertainty.

Diversification is a usual way in which farmers try to minimize agricultural risk, both diversifying crops and diversifying jobs. The first one is based on the logic that if one crop gets a low price, probably the others do not; and also on the hope, probabilistically based, that not all diverse crop are going to be infected by the same plague or disease. Yet, it is possible (and probable at a certain level) that a climate or drastic weather change will affect all crops. That is why a second diversification is also used, looking for different options to farming their land.

Those options include paid jobs for men in both agricultural and non-agricultural related work. Examples that can be seen at Vaquerias are the paid jobs for specific work, such as tractor driving for planting or harvest, and irrigation equipment moving for neighboring landowners. Examples of non-agricultural jobs are house construction and fence installation.

It has been said that women practically do not do crop work, thus all activities they can do to increase income and to help diversification, is to sell things they buy or cook.

Crop diversification however, deserves special consideration here. On one hand, though it is true that farmers plant different crops, only one of them (sorghum) is intended for the market. This doesn't help to avoid any low market prices, nor sorghum diseases. On the other hand, the two other crops (maize and beans) are the perfect expression of the minimum "count on" strategy. That is, if sorghum fails, they assure their annual food supply through having enough maize and beans in addition to eggs, chicken and perhaps sheep or goat.

Diversification of the commercial crop could be possible on a crop rotation plan or between households, but today's situation regarding land leveling, a side roll irrigation system, and some tractor driven crop works as planting, weeding, fumigation and harvest, makes it easier to have just one commercial crop at a time (per season). Maize and beans are planted outside, bordering the commercial crop fields, or on a small part of the grassland assigned. The border of the commercial crop gets some irrigation, the other not.

Another note about diversification is the idea of achieving more with the same resources. All interviewed farmers mentioned that investment money is the principal constraint, but then on second thought, they talked about the market and the high value of the work time. Finally, most of them agreed time is the main restriction and a good reason for selecting a low-demanding crop is that it allows them to look for diverse income sources.

Agricultural activities

Similar to the case reported by Bastidas in Ecuador (E. P. Bastidas, 2001), among the production activities, irrigated crop production is the most important economic activity for the small farmers in the livelihood system studied here. Farmers engage in crop production as field owners, sharecroppers, and hired farm laborers.

Crop Production

All of the farmers in the ejido Vaquerias cultivate maize and beans for home consumption, and sorghum as the commercial crop. Maize and beans are Mexican traditional crops, and they are part of almost all common Mexican dishes on a daily basis. Reasons why ejidatarios sow them for home consumption instead for the market have their origin in tradition; the typical low prices for those crops; difficulties to control large surfaces of crop management; and the usual low yields they have. Some of those conditions are changing, and different decisions could now be optimal for the new farmers.

In addition to the above, it is the option of sorghum as a commercial crop. Sorghum is a species that requires significantly less work and attention; it is better adapted to the hot and dry climate of the region, due to its higher drought tolerance; and it has a large regional market for use in feedlots and livestock production in this part of the country.

Moreover, the federal government used a governmental enterprise called CONASUPO to established points to receive all the sorghum grain that farmers could produce and then sell it in general good conditions. That enterprise established a minimum price that every private buyer had to respect. That way, ejidatarios assured a market for their product at a minimum price that paid for inputs. CONASUPO no longer exits. Ejidatarios claim for a governmental local place to assure the sorghum grain reception and to eliminate transportation costs. It is a clear expression that sorghum has lost that kind of advantage over other crops.

Maize and beans cover just half to one hectare of each household land, totaling not more than 60 hectares. Sorghum takes the remaining 1000 hectares of the ejido's cropland. However, it has not always been this way. The Vaquerias Project and some trials with small investors have been taken in the past to plant wheat and soybean, and even some vegetables in a small area.

Land.

Each ejidatario has exactly 66 hectares besides the house land. Family houses used to be in the fields, but factors like flooding, the need for community life, and the need for better utility services, guided planners to concentrate in an "urban" zone. A central almost empty square is surrounded by a health center clinic, the Catholic Church, and a place called "Comisariado" (commissariat), originally intended for ejidatarios meetings and used for all community social and work meeting events. There are also three schools: kinder-garden, elementary, and technical junior high school. This last one includes an agricultural technical instruction. From this main community center, streets and blocks were traced, with portions of 40 x 60 meters each. Plots were sorted between ejidatarios, and houses of adobe (clay blocks) were constructed for each family, all the same. Almost all of these houses were destroyed by the hurricane Gilbert in 1988 and alternative constructions were then made by the same inhabitants.

Each ejidatario (now farmer) then, has a 40 x 60 m plot in the urban area (plus a little one on a strip left aside by the planners), eleven (11) hectares of irrigated land for crop production, and 55 hectares of grassland with no irrigation, intended for livestock.

Adult men do most of the fieldwork, while women and boys could help with activities like planting, weeding by hand, and harvesting, which depends on the species grown and the cultivation system. Sorghum cultivation requires no woman field work. Mechanization has strongly reduced the need of labor.

Market.

During the Vaquerias Project time, one of the associated, private corporations, was a wheat flour processor, and it offered to receive all the wheat grain production. Once the project finished, ejidatarios left wheat and soybean production and came back to sorghum, but without the CONASUPO's reference and help. Near harvest time, today's new farmers go in groups looking for possible buyers, which are usually found at the feedlots. Sometimes the buyers go to the field with their own trucks, at other times, producers need to rent and pay for transportation of the grain. Relationships between feedlots firms and these grain producer farmers strongly support the decision of continuing planting sorghum.

Vegetable Production

No vegetable production is seen in Vaquerias neither fruit trees nor perennial crops are produced. In spite of those 40 x 60 m courtyards (solar) next to the houses, no gardening activities are followed. That is probably because of lack of knowledge, and tradition on water use. Even though they have water from the dam coming by tubes to the houses, water used is not only for this community, but it is shared with at least three more communities for irrigation and two more for household use. In addition, one more community wants to keep certain level of water in the basin for fishing and recreational activities.

Both men and women say the backyard soil is not good for vegetable production; and that there is too much sun and lack of water. It can be said that they developed certain respect for water, after years without irrigation. However, it is obvious that tradition (or the lack of one here) weights on this decision. Some have started to think about it. They acquired their few vegetables – mainly onion and tomato, from a traveling vendor.

Animal Production

Small Animals.

All families have small animals for home consumption. These always include hens for eggs and sometimes meat. Most households have hens that range freely around the yard, but some have them closed in a big corral. Commonly, women look after the hens and take control of the money when they are sold.

Most households also have sheep and some of them have goats. When the number of these small ruminants is less than 20, they are in a corral in the backyard; but a few households have achieved little larger groups that are kept on the grassland. Goats are a cultural tradition in the region, yet the ejido Vaquerias has just a small quantity. They are being pushed out by the farmers due their feeding habits; they consume young leaves and leave bushes nude, and unproductive.

While men look after animals on the grassland, both men and women take care of small animal in the courtyard's corral. Sheep and goats are fed with forage from the cropland. After the crop of grain is harvested, bunches of maize straw and rolls of sorghum forage are moved to the house to feed the animals.

Farmers consider that sheep are similar in many aspects to goats, but are less difficult to feed and manage. Sheep are of a variety called "pelibuey" which means they have no wool and have hair similar to a bovine. Goats and sheep are used for family consumption in parties and special occasions. People think they could be a good business enterprise, but the internal market practically does not exist (eventually one farmer buys a sheep from another), and the external market has not been explored.

Livestock

There are no milk or dairy cows on the ejido land. A few ejidatarios have herds of cows on the grassland. Men are responsible for feeding, watering and herding. The main product is the newly weaned calf and the secondary products are the old cows. Both products are sold in the place (grassland) to an intermediary (middle man) known as "coyote", who is capable of buying animals on individual basis and transporting them to places where they are going to be grown and fattened together with other animals.

Until now, the grassland area has not been physically divided. That means that each ejidatario knows which is his plot of land, but there are no fences to limit them. Therefore, cows may move over the entire grassland and eat grass and bushes from everyone's land. Now that ejidatarios have their ownership papers, they have initiated some investment in fencing and making small dams to keep rain water for animal intake. All this is just started and it is at an incipient phase, but surely will show consequential results on both, development and household differences, in some more years from now.

Other Activities

Several diverse activities are fulfilled by people in the ejido, beside the crop production that they do as landowners. When farmers do not need to work in their field, they look for a paid job in order to add income to the household. It is a common practice to have a group of men helping each other. Sometimes they are paid, and sometimes they are not, because they all need help from the others, and the whole group realizes the needed work for all of the group members. However, most people look for paid job on activities different from crop work.

Even in the case of the widow heads of household, crop production is their principal economic activity, as either field owners or sharecroppers. Animal production is the second contributing income activity. Beside that, men work in activities like construction (as salary paid workers in the city, or for their own, at the ejido or neighborhood), repairing fences, herding other's livestock, or taking care of a beer-drink place.

In the case of the wives or the female heads of household, a lot of work has to be done, both in and out of the house. However, practically taking care of a non-established, small store is the only activity that contributes household income. The very sporadic sale of any of the small animals adds money to the female money management.

Other work that women do without payment includes helping other women with children, taking care of the health center's installations, and looking after the medical doctor in turn. In the same way, they take care of church installations and teach religion to children.

Teachers of the schools are not from the ejido and, with the exception of just one of them, do not live there. Children go to school and they are not involve on crop production activities until they are 12 years old and enter the secondary (junior high) school.

There is no need for water fetching or wood gathering for fuel, since they have running water and gas stove in their houses, as well as electrical service. A boy is paid to go every morning to start the engine of the water pump for water to arrive each house.

Gender analysis: Women's Participation in Crop and Livestock Production

During the household interviews, both men and women were explicitly asked about women's participation in crop activities. The answer was unanimous:

they were surprised. Once the surprise passed, both genders agreed that the field work is hard, that it is men's work, and that women do not need to do it because of mechanization. Evidently, women participate in crop activities indirectly, supplying logistical support, for example, by preparing food for workers (family and paid ones).

The above reflects some cultural ideas, tradition and norms. "The field work is men's work, as the house work is women's work". Both genders also agreed that today's situation is adequate for that division of work, but in the past women have participated more in the field; depending on the species being grown, the work conditions, and especially the need for their work.

Bastidas (2001) established a logical relationship between participation in work and participation on decisions. "Women who participate more in crop activities tend to have greater influence on decision making." However, her own data show much more participation on decisions than participation in work. The same case was found at the ejido Vaquerias.

Women say that they do not participate in crop production work, and show support and respect for their husband's decisions about the crop, even though most of them claim to be consulted by their husband. However, decisions about how to spend the money are a different story. Three types of money administration is possible to identify here:

1. Men deciding and taking care of the money. Just giving a very small quantity to the wife, for family common expenses.

2. Both, man and his wife, arguing (negotiating) on how the money must be spent, according to the needs and goals of the family, and the woman managing the expenses. This type includes some cases in which the husband resigns to his right in behalf of the wife.

3. Both man and his wife decide on the way they plan to spend the money, and both manage it according to the plan.

Table 3-1. Gender division of labor.

ACTIVITIES		MEN	WOMEN	BOTH
Crop (sorghum, maize, beans)	Land preparation,	√		
	Plowing,	√		
	Planting,	√		
	Weeding,	√		
	Fertilizing,	√		
	Irrigation,	√		
	Fumigating,	√		
	Harvesting,	√		
	Threshing.	√		
	Storing,	√		
Livestock	Herding	√		
	Feeding	√		
	Forage gathering	√		
	Watering	√		
	Maintenance of fences	√		
Small Animals (sheep, goats, and hens)	Maintenance of the corral	√		
	Feeding			√
	Forage gathering	√		
	Watering		√	
House	Preparing food		√	
	Cooking		√	
	Cleaning		√	
	Washing		√	
	Child care		√	
Community	Taking care of Health Center		√	
	Taking care of Church		√	
	Taking care of Commissariat	√		
	Taking care of the schools			√

Source: results from sondeo, surveys and interviews.

Under the current situation, no decision is made about the amount of crop that should be left at home, or about the cash needed for the next agricultural period. This is because crops for use home are maize and beans, and farmers keep the entire production. The commercial crop is sorghum, and they sell the entire grain production, taken some pasture for the animals. About the money for next cropping season, farmers obtain loans and repay them after the harvest is sold.

The Linear Programming Model

General considerations

Linear programming (LP) was used to represent the households' current situation. The simulation of the Vaquerias community was done using the results of all sources of data: the sondeo, the survey, the in-depth interviews and even the oral stories.

Due to the farm systems homogeneity perceived during the sondeo, a one-year LP model was developed in sequential form; that is, incorporating more information as each new household was interviewed.

Model's simulation results exactly met the real data, and that validates the model. The simulation results were analyzed at the farm level in different scenarios, considering the community to have homogenous farm systems.

Since LP is an optimization tool, the model was intended to maximize family discretionary cash at the end of the year after satisfying family major food consumption needs. The LP model includes the following systems' characteristics:

Seasons: There are two well-defined growing seasons for crop production (the first season, January to June; the second one, July to December), and an annual cycle for animal production. The model incorporates that as season 1 and 2 in a divided basic matrix.

Land: It is a very interesting variable because not only it is a limited resource, but land use is restrictive in reference to the irrigation system, presenting some decision oportunities on the grassland or nonirrigated crop production.

Land acquisition: Even though farmers are allowed to buy-sell and/or rent land, they are not doing so, yet. Even people who leave the ejido to go to the USA are keeping their land. Some families have joined son-fathers' land, and it is probably right to expect the renting and buying- selling period is forward. Renting and buying-selling operations are not included in the model, as farmers are not considering it as current realistic options.

Family Labor: This is not a limited resource, but it is a cost-generating one. Although only adult men work in the field, they have plenty of time to do it, yet this time competes with off-farm, non-agricultural paid jobs. Usually young men from the same family ask for some money as payment for their field work, even though they would be likely have to do it without payment when necessary.

Paid Labor: The household has the opportunity to hire people, since labor is available in the ejido. But this is just happening in labor intensive operations. People hired are from other households in the same ejidal community. Thus, it is also common that household members work for others (off-farm labor), more than to supplement household income, to help, paying the attention service. All the interviewed farmers consider paid labor as a cost, rather than a possible income. A hired man cost $100 per day and the highest need is to hire 3 people a day for 5 days to help with harvesting and load trucks work. An exception is the $120 per day paid to a friend for an irrigation day. Remember that irrigation is made with an automatic side roll system that takes just one person to push down the button of the car, and change tube connection to the next one when the side roll reaches the limit of the previous pass. However, the side roll will pass to irrigate the next farmer's field and one can lose the opportunity to irrigate if he is not ready on time. That is why this paid-work is so important.

Water: House's running water is not a limited resource, nor is water used for small animals in the house's courtyard. Water for livestock and other animals in the grassland depends on facilities (as small water reservoirs) and men work to supply it. Irrigation water is not a limited resource, as far as the dam construction and irrigation system suffer no damage. *Rainfall* is not enough to achieve a high yield from a non-irrigated crop, but there is enough rain, in addition to the Conchos river's water, to keep a good water source at the dam. Farmers know what it is like to not have irrigation water, and they try not to use it more than three times a crop season, yet sometimes a fourth is required. The use of that water was assumed to have no cost.

Irrigation system: The way irrigation equipment works is to limit the crop choice. That is, the side roll sprinkler height allows the short crops to grow, but they are lower that tall crops like maize. That means that irrigated maize is limited to the border of the irrigated area, which is one hectare per farmer (who owns eleven hectares for irrigated crop).

Credit: Minor credit is available through suppliers for minor animal production activities. For example, they can get fuel to have some cactus burned to feed animals, and pay for it when a calf is weaned and sold. Unlike that, major credit is a tough and key issue. Major credit, necessary to cultivate the land and produce the crops, was widely available when ejidatarios were not owners, through government bank BANRURAL, then they had investment money from the associates in the Vaquerias Project, but after that, they learned they were not a credit subject for a common bank. Today, credit is available if they have some kind of organization and ask for it through a para-financier, which is a firm that controls governamental funds without being a bank. Agri-industry, agricultural inputs suppliers and/or technical advisors organization could be a "parafinancier" if approved by the government. All this means that the Vaquerias farmers can get credit from a parafinancier for their agricultural operations, but must to keep it to the lowest possible, because they already have a big credit they got that way and used for reinstalation of the irrigation system.

Initial cash: Credit for agricultual operations at Vaquerias works on a refund basis. Thus, farmers need to assure a minimum amount at the beginning of each season to start operations, besides their houses' expenses and needs.

Cash use: There are three totally separated groups of activities on cash use without mixing between them. Agricultural production expenses, house and small animals expenses, and livestock expenses. Model incorporates this feature making a modular matrix that can be divided in sections reflecting a small matrix for each season and kind of activity..

Cash transfer: the cash, if not used in the first semester, can be transferred to the second semester. If the cash in the second semester is not used, it is transferred to the end of the year cash.

Agricultural activities: There are no perennial crops. Commercial crop is just sorghum, while maize and beans are planted for house consumption. As discussed at the risk management section, there is not much diversification on commercial crop, and that does not help to avoid plant disease. Last season (on September 2002), sorghum presented ERGOT, a disease caused by the fungus Claviceps purpurea, that causes reduced yield and quality of grains. Some farmers are thinking to change the species to plant the second semester of this year. They are thinking about beans, which is a species they know well. Irrigated beans is incorporated to the model as a possible enterprise choice. At the same time non-irrigated maize is included: maize is planted for irrigation, but it is possible to have some non-irrigated maize out the irrigated land.

Animal production: This comprises small animals as hens, sheep and goats, and also livestock.

Consumption habits: Family and hens consume maize grain produced on the farm. Sheep and goats consume pasture from maize and sorghum. Livestock graze on grassland. Family also consume beans produced on the farm, eggs and chicken from the hens.

The mathematical model and the spreadsheet

The mathematical LP model is:

Opt: $Z = \Sigma_i C_i X_i$ where $i = 1 \ldots n$

Subject to: $\Sigma_j C_{ij} X_i <= R_i$ where $j = 1 \ldots m$

X_i is unknown, but it is $>= 0$

Ci is the correspondent coefficient for the Xi variable

Z, the objective is, in this case, annual family profit.

The Vaquerias farm system model is made for various blocks or submodels, divided into two seasons, given k = 1,2 for season. That way, the mathematical expression is:

Maximize: $Z = \Sigma_i C_i X_i$ where $i = 1 \ldots n$

Subject to: $\Sigma_{jk} C_{ijk} X_{ik} <= R_{ik}$ where $j = 1 \ldots m$; $k = 1, 2$; and X_i is the unknown decision variable, but it in this case is always >= 0

$X_{1\ldots6}$ are crop production variables representing the amount of cultivated hectares of each crop.

$X_{7\ldots11}$ are market selling variables for different crop products.

$X_{12\ldots15}$ are consumption variables.

$X_{16\ldots21}$ are animal production variables.

$X_{22,23}$ are variables corresponding to other productive activities

X_{24} is the necessary money to cover house expenses.

X_{25} is an option to save available money that exceeded the operations.

X_{26} is variable that allows to transfer surplus money from the first season to the second one.

X_{27} is the incoming money through the Procampo program for each cultivated hectare of land.

X_{28} is the amount of money that it has to be obtained from credit.

Financial sub model

To be able to produce, it is necessary to count with investment money. The financial sub model is represented by variables Xik where i = 24…27 , and k = 1, 2; expressed like:

Capital: Initial cash, Procampo, Transfer cash, House cash, and Final cash.

Initial cash is the necessary investment money coming from credit and the Procampo program, and being used to invest in production activities, and to pay the house expenses. The mathematical expression is:

IC: minus investment money on productive activities minus house expenses plus financial money. That is:

IC: Σ $-1550X_{1\ldots6}$ Σ $-600X_{17,18}$ Σ $-1X_{24}$ Σ $1X_{26,27} = 0$

$X_{1\ldots6}$ are crop production variables representing the amount of cultivated hectares of each crop and 1550 are the expenses for each hectare of the correspondent crop.

$X_{17,18}$ are animal production variables and the 600 coefficient is the needed money to buy a reproductive female of the correspondent species.

Procampo is a governmental program that tries to motivate land cultivation by helping campesinos to pay some of the expenses they run in when they make fieldwork. Procampo pay a fixed amount per planted hectare once a year or season. In the first semester of 2003, Procampo paid 875 per hectare and it is expected a 1000 Mx$ for the second semester season.

Procampo: $\Sigma\, 875X_{1...6}\ \Sigma\, \text{-}1X_{26} = 0$

$X_{1...6}$ are the amount of cultivated hectares of each crop and 875 are de Mx$ obtained for each cultivated hectare.

X_{26} was described before.

House cash, states the amount of money usually spent in family and house expenses during the period. $X_{24,1} = 750$ (Mx$)

Final cash sum the total income from productive activities, pay credit and reports the available cash for discretional use by the household.

Final cash: $1.2x_7 + 200x_8 + 1.5x_9 + 8x_{10} + 3x_{11} + 300x_{20} + 0x_{21} + 120x_{22} + 250x_{23} + x_{25} - 0.5x_{26} + x_{27}$

The financial submodel is:

IC: Σ -1550$X_{1...6}$ Σ -600$X_{17,18}$ Σ -1X_{24} Σ 1$X_{26,27}$ = 0

Procampo: Σ 875$X_{1...6}$ Σ -1X_{26} = 0

House cash: $X_{24,1}$ = 750 (Mx$)

Final cash: $1.2x_7 + 200x_8 + 1.5x_9 + 8x_{10} + 3x_{11} + 300x_{20} + 0x_{21} + 120x_{22} + 250x_{23} + x_{25} - 0.5x_{26} + x_{27}$

Crop production submodel

In the same way that the financial submodel, and powered by it, there is a crop production model that defines the total yield of each crop in base on the amount of hectares that were decided to be planted of the corresponding crop. Production is an average estimation according to the typical behavior of those crops in the area, and the farmer's expectations. That production has destination to family consùmption (maize and beans) and/or the market sell (sorghum), and it is limited by land, labor and technical constraints.

The crop production submodel comprises grain production of sorghum, maize and beans; sorghum forage rolls, and maize frage (straw bunches). Expressed as:

Sorghum grain: $3000\ x_{101} + 2000\ x_{102} - 1x_{107} = 0$

According to the above definitions, that expression means that it is expected 3 tons of sorghum grain per hectare in irrigation land, and just 2 tons on non-irrigated land. The whole production goes to the market, and all this happened during the first semester season (hundreds sub index). During the second season, the expression is: $2000\ x_{201} + 1000\ x_{202} - 1x_{207} = 0$, as sorghum crop is ruined by the Ergot.

Similar equations exist for maize and beans, as well as for the forage. Limitations are the already mentioned about the high of the irrigation system, that allows just 1 (one) hectare of irrigated maize. Other limitation is the availability of non-irrigated land, since in spite of having 55 hectares of grassland, investment implications to prepare them for crop production, and the conservation criteria, limited the use of that land, also to one hectare. Labor is an interesting constraint affecting both, the availability of days to work off-farm, and the cost of the crop operations, increasing this as the crop need more attention. Finaly, Ergot not only reduced/s yield, but also the market price.

An expression of labor in terms of man/day is:

$$6.5X1 + 6.5\ X2 + 8.5X3 + 8.5X4 + 10.5X5 + 10.5X6 + X22 + X23 <= 150 \text{ days.}$$

This equation shows the increasing need of the own labor from sorghum (both, irrigated and not), to the beans, with the higher necessity of labor. As this affect the hired labor, the investment money and cost of the crop is affected as well.

Animal production sub model

At the ejido there are incipient animal production enterprises. While all households have hens, no one considers them as a possible business, but for own consumption. Since everyone has his/her own hens, there is no market for them. Hens produce eggs and chicken for the house, and an eventual sale or exchange. Other animal production enterprises are the sheep, the goats, and the cows. Just a few people own these animals, with a small but well-established market procedure. Small ruminants and cows take advantage of the sorghum and maize forages.

Other sections

The model includes a section to define the family food consumption needs, and relates them with crop and animal production, assuring this before they go to the market.

It is also included a little but important section for paid off-farm works that competes for labor-days with the farm enterprises. This job has the advantage of the lack of investment other than time.

The whole model can be observed in the appendix 2 as in the general format for linear programming, and in the appendix 3 for the spreadsheet expression.

ELP model's results

The model generated results that reflect very well what the farmers of Vaquerias have been deciding. In fact, the model has turned out to be rather robust while it mimics well the farmers' decisions, but these seem to be slightly sensitive to some changes. Simulating the case presented by the ejidatarios, about some of them who spend more money, doing a second and up to the third harrow; still adding the weeding and up to the plane fumigator, the response of the model continues indicating the same of the farmers decision makers. With the raise of the costs, the profit decreases, but the decisions of what and how much to plant, continue to be in favor of the irrigated sorghum. The farmers and the model decided to plant maize and bean only for self-consumption, and the sorghum to commercialize it. The final available cash of the first semester was in between of

45 and 50 thousand of Mexican Pesos (Mx$) (4.5 - 5 thousand USDolars) and, at the end of the year, it would be of 95 thousand Mx$ (aprox. 9.0 - 9.3 thousand US American dolars). However, from this money yet they have to pay part of the huge credit they needed to repair the irrigation system.

Although this model validation is more than enough to compare the current possible situation and make attempts to understand farmer's decisions, it would not suggest technical advisors or extensionists to use the models with confidence to try to predict future systems' performance. That mainly is due because of the changing current situation. What may be highly worth to do, would be a new survey some years from today, in order to appreciate community evolution, as affected by all political and economical changes. Evolution could lead to household diversification and consequently different farming systems expressions; as new livelihood options can raise at the community, driven by the economic success of ones and the necessity of others.

For the second cultivation period, instead of simulating what happened in the previous years, it was decided to work on the real situation of the second semester of the present year. This was, among other reasons, by request of the farmers, who have the plan of changing crops for the second cycle. The proposal was to expose beans crop as the commercial one, and again the model simulated the decision of the ejidatarios: beans will be a better option that the sorghum and the maize as commercial crop. Nevertheless, the model revealed that beans were already a better option in the second semester of 2002, when the farmers decided to plant sorghum. In this case, the explanation is direct, simple and provided by the same farmers: " we had not contemplated it. If we do it now it's because of the Ergot, which has ruined the sorghum ".

There are other crops, varieties and field operations that farmers have not considered; therefore, they are not part of the farmers' decisions possible choices. In the following chapter, advantage will be taken of some of the models that simulate the crop growth (Crop Simulation Models), to analyze real possibilities that enrich that choice of decisions, and to propose logical and viable changes in the model that simulates the farm system. All that with the intention of helping to improve the farm system, but especially, of taking the opportunity to analyze and to learn about the processes of decision making by the new farmers.

CHAPTER 4

SIMULATING CROPPING SYSTEMS: USING CROP SIMULATION MODELS TO ENHANCE DECISIONS MAKING

Introduction

Farmers have always chosen, among the all-possible enterprises, which ones have to provide livelihoods for their household. They make decisions to design their farming systems. Among all these decisions, to decide which crop to rise is by far the most important one. That decision establishes a backbone to support all the other decisions and may be the difference between success and failure of the system, but a group of constraints frames it. As farm management changes have become more competitive, so have the managerial skills needed, especially for new farmers with a new decisions' environment.

Vaquerias' farmers used to raise sorghum before the "Vaquerias Project", during which they cultivated wheat and soybean, and they have come back to sorghum after it. Today they are facing the possible decision to change commercial crop to beans for the second season of the year, because a sorghum disease showed up last year (2003). Naturally, a series of questions emerges about the crop decision: Are beans the best option? If it is so, why did they not use it before? What about the crops selected by general managers of the Vaquerias Project (wheat and soybean)? What about any other possible crop? How to make this decision?

Certainly, farmers could use all accurate help for decision making. Decision Support Systems (DSS), from the informatics systems field, have been helping decisions making process of non-farmers managers for years. A (DSS) can be broadly defined as a computer-based information system that affects or intends to affect the ways in which people make decisions (M. S. Silver, 1991). DSS basically provides the required information to make a better informed decision. They are generally based on a situational assessment and simulations to allow decision makers to attempt to forecast the adequacy of a course of action (G. A. Klein, 1989). An agricultural DSS could bring information to Vaquerias farmers and help them make a good decision if it is able to correctly assess the crop situation and to accurately simulate it.

Literature review

Decision Support System for Agrotechnology Transfer (DSSAT), is an integrated decision support system that contains several computer-based crop simulation models (G. Y. Tsuji, G. Uehara, & S. Balas, 1994). Its purpose is to help agrotechnology transfer by providing a user interface that allows one to manipulate those models, which attempt to simulate crop growth and yield at any place (G. Uehara, 1989).

Simulation of a certain cultivar's performance under different weather and soil conditions is possible because models respond to environmental variables, like daily maximum and minimum day temperatures, solar radiation, and precipitation, as well as to crop management conditions. Since the 70's several models have been proposed to simulate crop growth (G. G. Wilkerson, J. W. Jones, K. J. Boote, K. T. Ingram, & J. W. Mishoe, 1983). Today, crop simulation models, designed to mimic the crop responds to the weather, soil, water, and management conditions, have been widely validated after modifications to actually meet requirements for a confident simulation (H. Lal, G. Hoogenboom, J. P. Calixte, J. W. Jones, & F. H. Beinroth, 1993).

DSSAT is a product of an effort initiated with special interest on developing countries. Yet most of the DSSAT related experiments reported are from the U.S.A., Canada and Europe, a growing number of developing countries have been using it. Until now, no Mexican institutions have been involved in the DSSAT project. However, some educational institutions, like ITESM (Monterrey Tech) and one important research institution, "Centro para el Mejoramiento de Maíz y Trigo" (CIMMYT), have been using DSSAT models in a limited way, especially the corn and wheat models, without any published report about those works.

Among the models integrated into DSSAT there are the CERES-sorghum and CERES-wheat (J. T. Ritchie, D. C. Godwin, & S. Otter-Nacke, 1991), as well as the

Methods

General

In order to reach the objective, this project used the DSSAT program version 3.5, which is an upgrade for the DSSAT v2.1 and DSSAT v3.0 systems released in 1989 and 1994, the history of which is published by Uehara (1989), and Uehara and Tsuji (1991). DSSAT is documented in its own manual (G. Y. Tsuji et al., 1994).

Data needed to run the simulation model are: a weather data file, a soil data file, and an experiment data file. This last one has to include the reference of the appropriate cultivar, genetic coefficients data of which must be available in the DSSAT's genotype file. Files must be in the appropriate DSSAT's format.

Weather data

A file containing growing season weather data for each involved site was needed. For the Vaquerias site, the files TMVA0201.wth (for the second semester of 2002) and TMVA0301 (for the whole year of 2003) were formatted. Since no weather station is operating in site on Vaquerias field, data for those files were calculated as the weighted average (weighted by distance), of 20 years monthly data obtained form three different weather stations surrounding the site: General Terán, El Popote 1 and

Cerro Prieto. For the Apodaca site, the file TMAP02Ol.wth was created using weather data obtained from ITESM corresponding to the 2001-2003 wheat-growing season. In both cases, weather data files include: daily maximum and minimum temperatures (TMAX and TMIN), as well as precipitation and solar radiation (SRAD) on a daily basis.

Soil data

Two agronomic wells, one for each of the main soil types, were made at Vaquerias site. Soil samples were taken for each soil horizon and analyzed in a commercial soil laboratory. Obtained data helped to write TMVA0301.sol and TMVA0302.sol soil types into de TM.sol file. The file also includes TMVA9101.sol, TMVA9102.sol, TMVA9401, and TMVA9402.sol soil data, corresponding to data taken in 1991 (at the beginning of the Vaquerias Project), and 1994 (the last year of the Project). Endings 01 and 02 are for white soil and black soil respectively. These files allow comparing current soil conditions and responds with those that exist at the Project time. Part of the TM.sol file, with all soil data mentioned can be seen in appendix 4

Crop data

Crops to be simulated and analyzed are the current commercial crop (sorghum), the previous commercial crops (wheat and soybean), and two of the possible future crops (beans and potato). Crop simulation models use "Genetic coefficients" to characterize each crop and cultivar genetic reaction to weather and nutrients. Those were obtained or calculated from field trials depending of the crop.

Current commercial crop

Sorghum is the traditional and well-adapted crop option for Vaquerias farmers. The need with this crop is to calculate genetic coefficients for the cultivar they are actually growing, and to simulate it under different weather conditions and management situations. About management, there is a special situation issue around the fertilizer use, since farmers report that they didn't notice any crop response to Nitrogen fertilizer applications.

Sorghum cultivar raised in 2003 was Warner 839, with unknown genetic coefficients. On-farm research was realized to follow growth stages and biomass production under natural commercial conditions. Biomass samples helped to know dates and dry matter data needed to calculate genetic coefficient for this cultivar. Once the genetic coefficients were ready, "experimental" files were created, simulating actual experiments with weather and fertilizer changes.

Previous commercial crops

Long lists of wheat and soybean genetic coefficients were available in previous versions of DSSAT's genotype files. DSSAT actualization has lead to CERES-Wheat model modifications in a way that genetic coefficients must to be re-calculated. A field plot trial specially designed to meet IBSNAT specifications and to calculate genetic coefficients, was conducted. The experiment was done at Apodaca site of Monterrey Tech (ITESM), during 2002 - 2003 wheat growing season, including four cultivars: Sonalika, Choix, Guanajuato and a new proposal from INIFAP. INIFAP stands for "Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias". It is the Research Institute of the Mexican Agriculture Ministry (SAGARPA).

Soybean growth simulation model SOYGRO, organizes the varieties that it includes in genotype groups. Those groups were simulated with different planting dates under Vaquerias soil and weather conditions, with the intention of identifying the group(s) that might fit the agricultural cycles in this *zone with an acceptable yield,* and to compare the soybean with other options.

Other possible commercial crops

Unlike sorghum, wheat and soybean that have been the selected commercial crop at Vaquerias in different occasions, beans have always been for self-consumption. However, it is a possible option worth to be analyzed. Beans cultivars were simulated under Vaquerias conditions, using the BEANGRO simulation model.

Another never-chosen commercial crop is potato. In spite of the fact that potato is the crop that produces most of the agricultural money income to the State, it is considered as a highland crop, not appropriate for the height of just 150 meters above sea level of Vaquerias. During the potato summer season of 2000, a field trial was conducted on-farm at Arteaga. Coahuila, México (J. C. Martinez-Porte, 2000). The objective of that work was to calculate genetic coefficients of three potato cultivars: Alpha, Gigant, and Mundial. Trial included cultivar Atlantic which genetic coefficients were already known. From that work, cultivars Atlantic, Alpha and Gigant were taking to be simulated under Vaquerias conditions.

Results

Site weather and data

Vaquerias location data was mentioned in the General Description of the Research Area section at the beginning of the Literature Review of the Chapter 3. Figures 4.1, 4.2, and 4.3 show average rain, temperatures and solar radiation from a 20 year (1982-2003) calculated weather profile. During that 20-year history, average annual precipitation was 590 mm, with a maximum monthly of 360 mm; maximum temperature average was 30.45, minimum temperature average was 6 Celsius. Resulting weather files are included in appendix 4.

Figure 4-1. Calculated average annual rain at Vaquerias (Gral. Terán) region

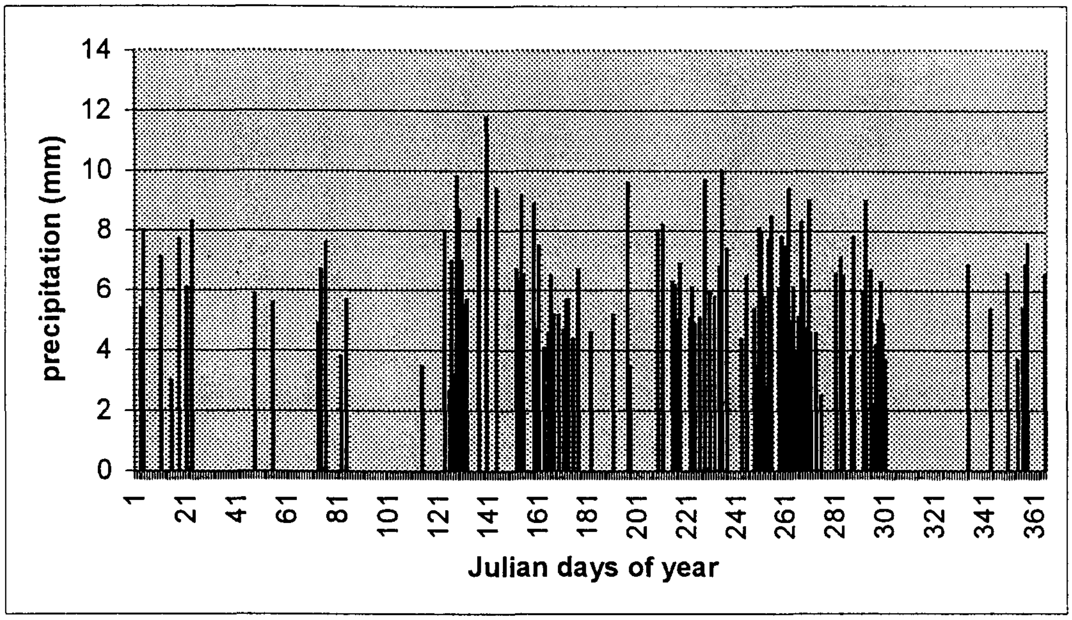


Figure 4-2. Calculated maximum and minimum average temperatures at Vaquerias region (Gral. Terán, N.L. México).

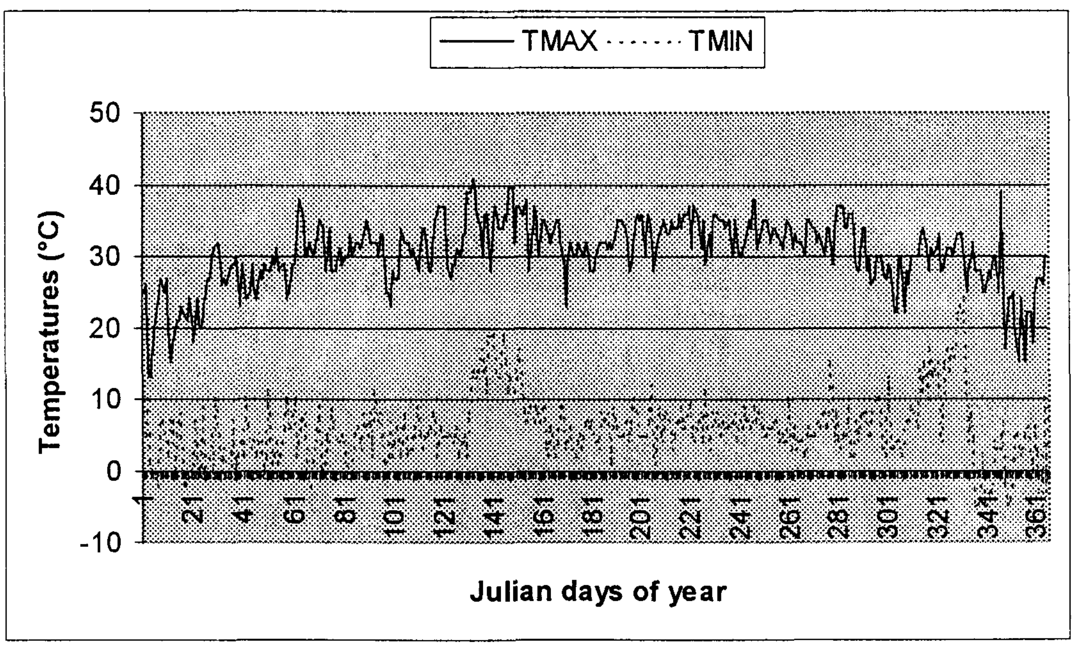
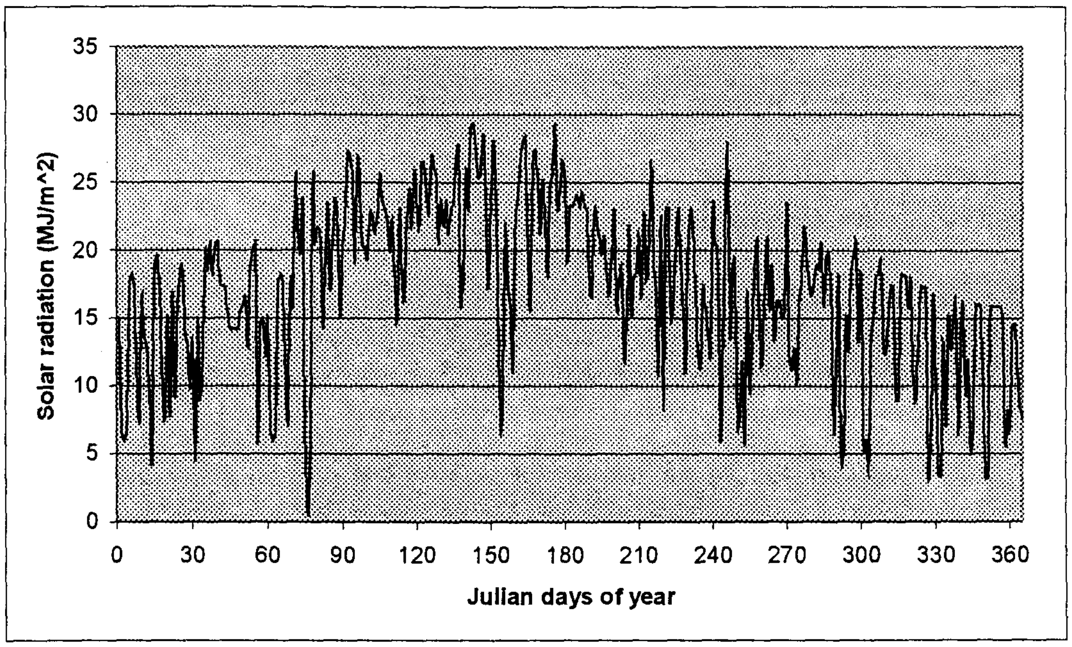


Figure 4-3. Calculated average solar radiation at Vaquerias region (Gral. Terán, N.L. México).



Current commercial crop

As a result of the analysis of biomass data taken on Vaquerias crop field, proposed genetic coefficients for simulation of sorghum cultivar Warner 839-DR with the CERES program are:

Genetic Coefficient	Proposed Value
ECO#	IB0001
P1	360.0
P2O	12.00
P2R	20.0
P5	540.0
G1	0.0
G2	6.0
PHINT	49.00

Where, according to the CERES model for graminea simulation, in the SORGHUM GENOTYPE COEFFICIENTS file (J. W. Jones et al., 1984) are:

Genetic Coefficient	Coefficient explanation
ECO#	Ecotype code for this cultivar. It points to the cultivar's ecotype in the ECO file (currently all cultivars are marked as ecotype IB0001).
P1	Thermal time from seedling emergence to the end of the juvenile phase (expressed in degree days above a basic temperature of 8°C) during which the plant is not responsive to changes in photoperiod.
P2O	Critical photoperiod or the longest day length (in hours) at which development occurs at a maximum rate. At values higher than P20, the rate of development is reduced.
P2R	Extent to which phasic development leading to panicle initiation (expressed in degree days) is delayed for each hour increase in photoperiod above P20.
P5	Thermal time (degree days above a base temperature of 8°C) from beginning of grain filling (3-4 days after flowering) to physiological maturity.
G1	Scaler for relative leaf size.
G2	Scaler for partitioning of assimilates to the panicle (head).
PHINT	Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances.

CERES-Sorghum model, in its genotype file, presents three wide groups of cultivars, divided by geographical region with their general coefficients shown in table 4-1.

Table 4-1 Genetic coefficients of the three general groups of the sorghum model.

@VAR#	VRNAME	ECO#	P1	P2O	P2R	P5	G1	G2	PHINT
990001	N.AMERICAN	IB0001	360	12.5	30	540	0.0	6.0	49.00
990002	INDIAN	IB0001	410	13.6	40	540	3.0	5.5	49.00
990003	AUSTRALIAN	IB0001	460	12.5	90	600	5.0	6.0	49.00

By simulate those general groups under Vaquerias conditions, it was found that North American cultivar groups are closest to meet the observed data. Which it is the logical result since Vaquerias is in North America, but Indian region is in the same latitude than Vaquerias. Table 4.2 shows comparison between observed and simulated data with cultivars groups.

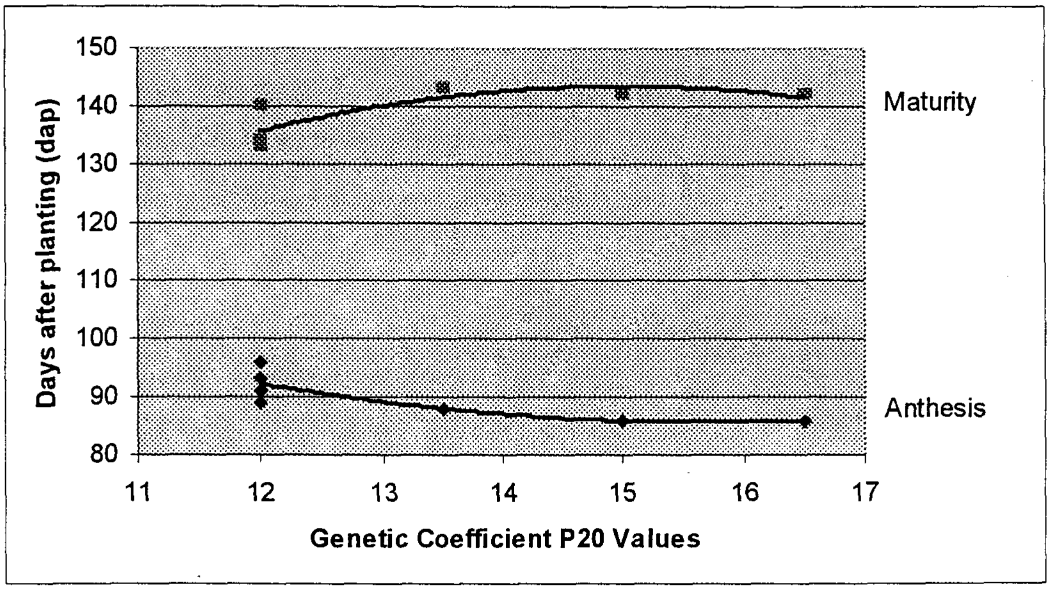
Table 4 -2. Results of sorghum cultivars groups simulation under Vaquerias conditions

Cultivars group	Flowering date (dap)		Physiological maturity (dap)		Yield (kg/ha)	
	simulated	Observed	simulated	Observed	Simulated	Observed
N. American	91	90	134	130	3360	3200
Indian	94	90	149	130	2942	3200
Australian	117	90	174	130	2394	3200

Given those results, North American group genetic coefficients were taken as the initial set. Each coefficient was tested according to its expected effect in the simulation. As an example of the adjustment, figure 4-4 shows the effect of the genetic coefficients P2O and P2R under needed days to arrive anthesis and physiological maturity. Coefficients' values are chosen to closely fit observed data

(90 and 130, respectively). Figure 4-5 presents a different point of view, showing the relationship between yield and the coefficients, being these depending (or selected in function) of yield. In that figure, (4-5) it is clear the closest relation with P2O coefficient, and the almost non-existing relation with P2R.

Figure 4-4. Effect of Genetic coefficients P20 and P2R under flowering and maturity days.



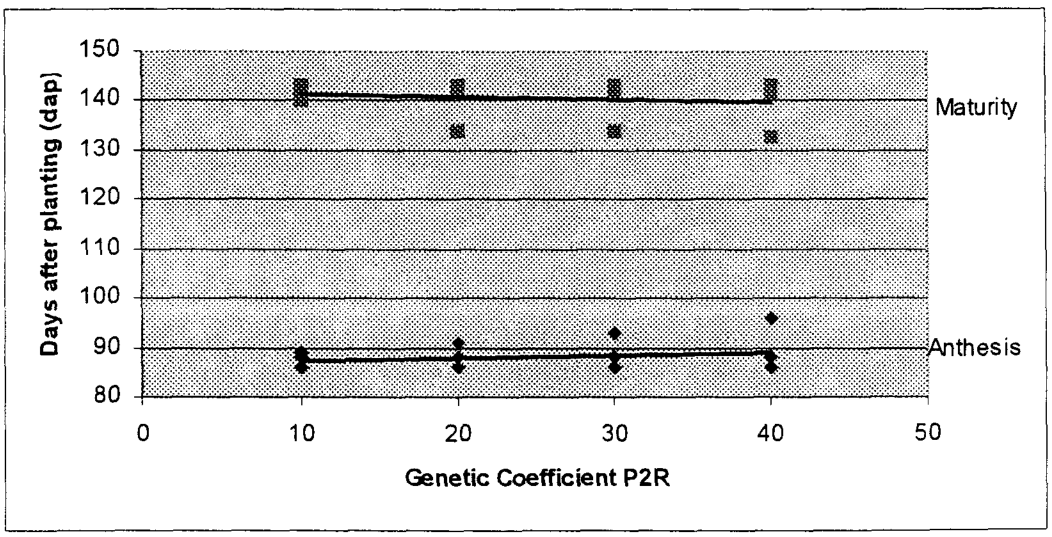
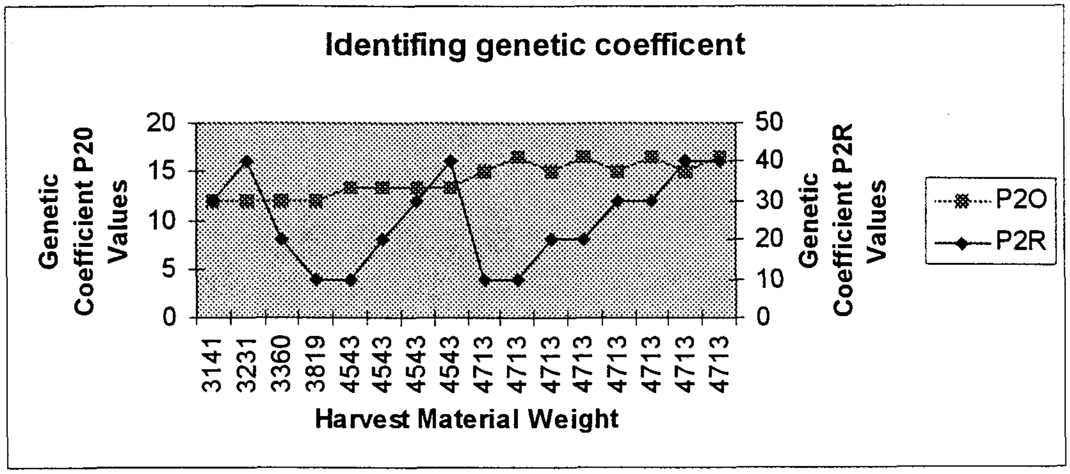


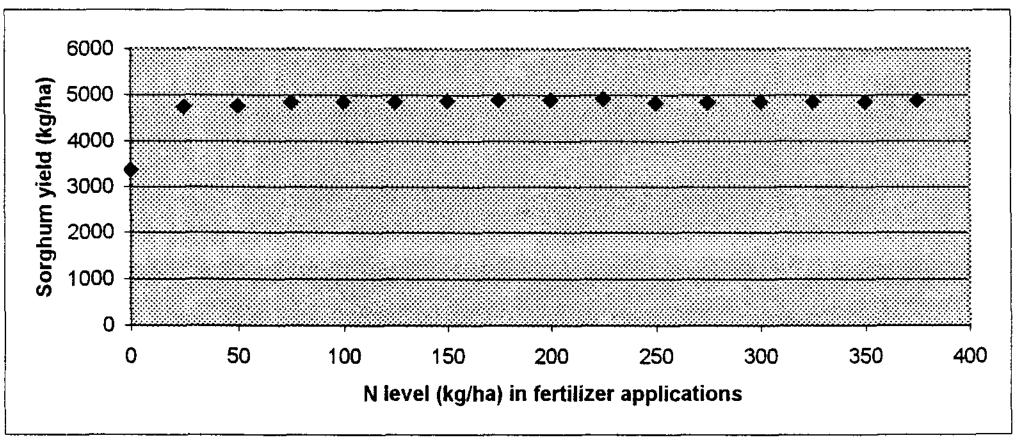
Figure 4-5 Relationship between genetic coefficients P20 and P2R with Harvest Material



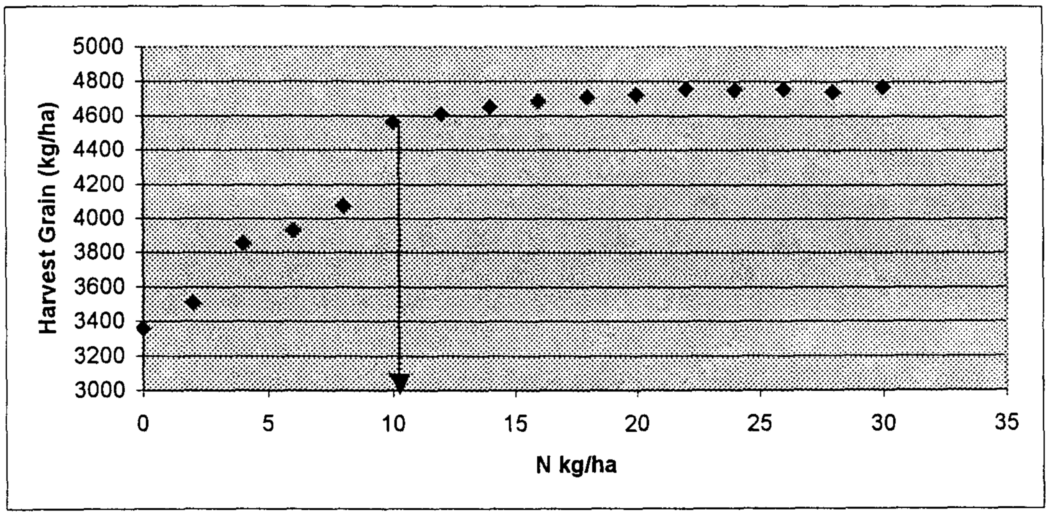
Once genetic coefficients were established for the purpose of this work, simulations head to challenge a farmers' decision, and to explore a weather sensitivity analysis. An interesting issue for operations management is the fact that, in spite of have used chemical (inorganic) fertilizer during the time of the Project, Vaquerias' farmers have decided to avoid using it for their own sorghum enterprise. They say fertilizer does not have any positive effect on sorghum yields, due the specific soils conditions.

This work took some soil samples, assured laboratory analysis, compared them with soil analysis reports form Vaquerias Project time (1991 and 1994), and run simulations to observed the mimic behavior of the crop system at this specific issue. Urea was the common used nitrogen fertilizer; same that was simulated. In figure 4-6 can be seen that crop has almost no response to variation on nitrogen (N) levels, which seems to support farmers appreciation of the system. However, simulated yields are higher of the observed real gained yield. A closer view (Figure 4-7) allows us to know that apparently could be a high good answer to small N quantities applications. Figure 4-7 shows that no significant yield is increased with N applications larger than the very small amount of 10 kg/ha, while a whole ton is earned with those 10 kilograms. Simulation results for a non-fertilizer sorghum production report N stress just in the critical stage of grain filling. That possible N application is one of the points where farmer's decisions differ from the simulation of a model that seems to accurately mimic the system, and bring material for analysis in following chapters.

Figue 4-6 Harvest grain as it is affected by large quatities of N application.



Figue 4.7 Harvest grain as it is affected by small quatities of N application



A simulation was also run with sorghum to have and to give an idea of what was to expect about the current cultivar behavior. Since hot weather and lack of rain are to characterize the region, a diminishing rain and increasing average temperature were simulated. Results of a less rainfall year are depicted on figure 4-8 for flowering and maturity dates, and on figure 4-9 for grain and biomass harvest. Due to river intake water into the impoundment, a dry year with even 40% less rain may allow farmer to manage at least three or the four irrigations. Today the irrigation program has a buffer effect that helps crop to produce up to 2.5 ton/ha even with a 30% less rain (Figure 4-9). Decrease of production is due to the lack of water, the crop suffers during the grain filling stage, since irrigation avoid water stress before. Figure 4-7 shows how the flowering date states the same, while maturity is rushed because of the water stress.

Figure 4-8 Effects of rain reduction on flowering an maturity dates

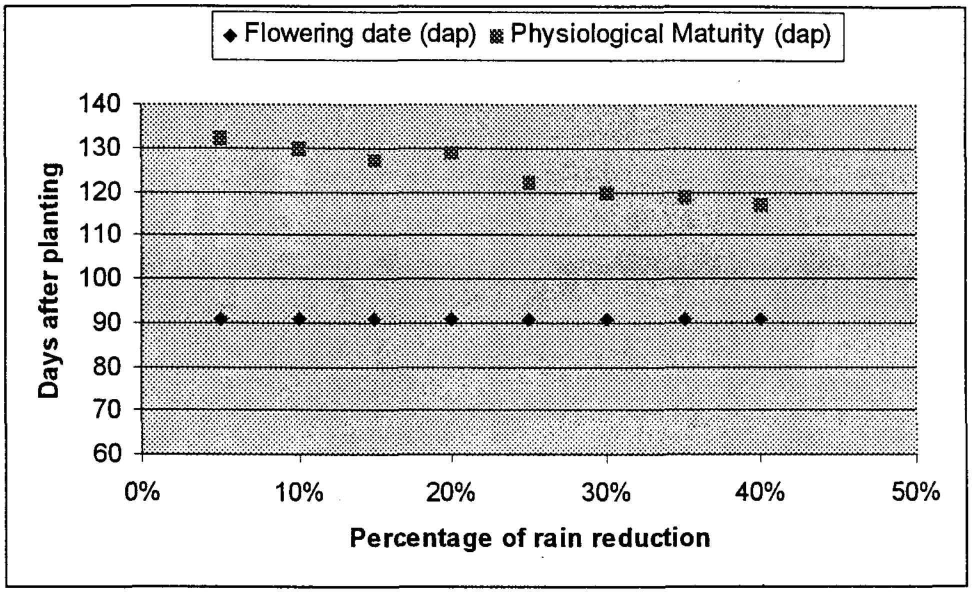
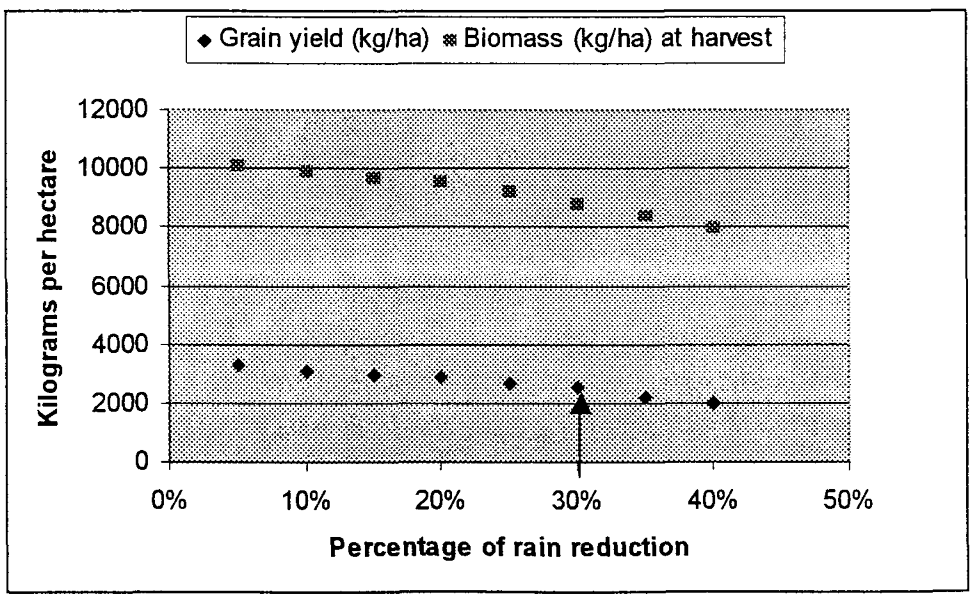


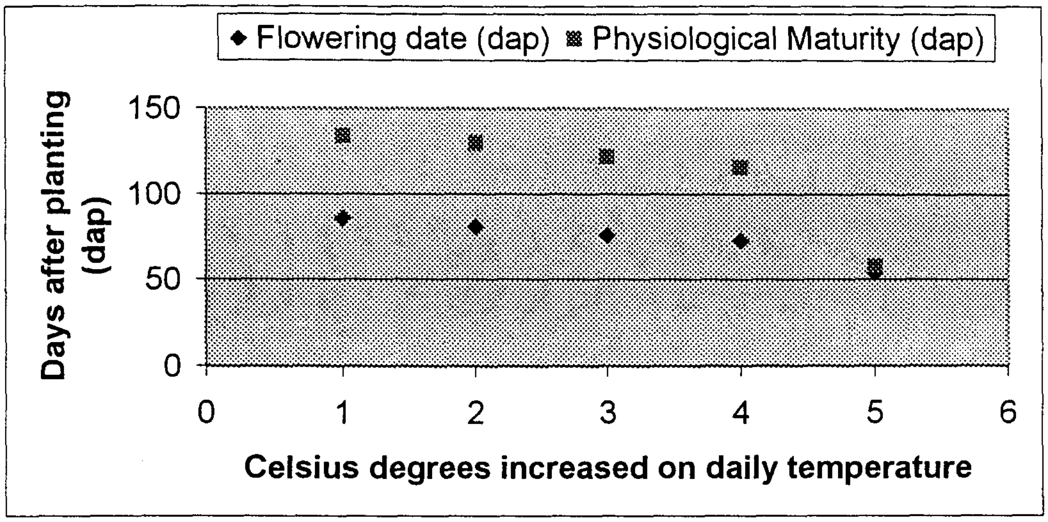
Figure 4.9 Effects of rain reduction on grain and biomass yield.

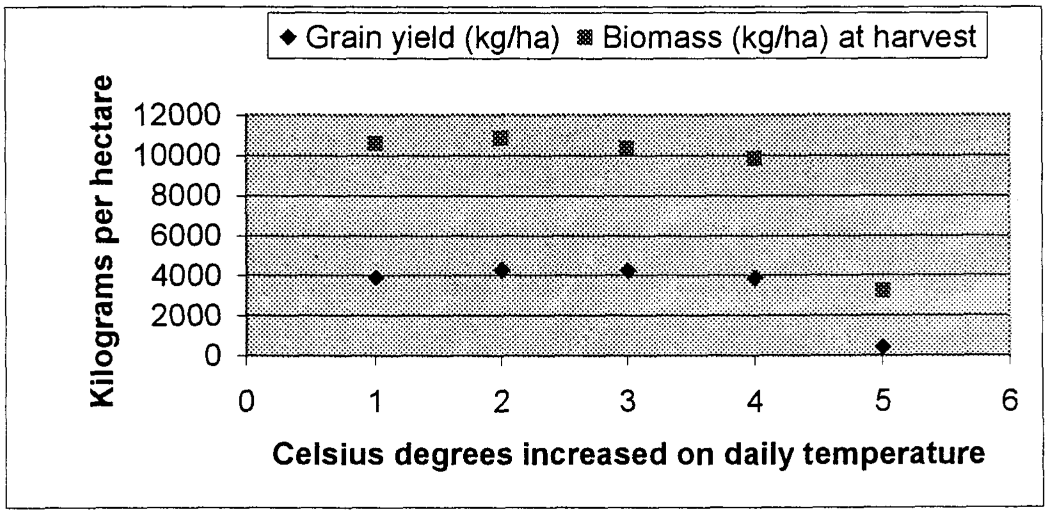


It can be said, by these data, that the current cultivar (Warner 839) presents an adequate behavior for the Vaquerias conditions, since it can tolerate well enough the presence of a dry year, and still have a good production. Temperature changes are shown in the figures 4-10. As it to expect, increasing temperature increases developing rate, diminishing needed time to flowering and maturity stage, by the faster accumulation of degree-days. At the same time, grain and biomass production rise to the optimum (2 more degrees, in this case) to come back later, until it becomes practically inexistent at an unthinkable temperature increment of five degrees. It is important to have in mind that Vaquerias conditions are mainly characterized and strongly driven by the irrigation conditions. Without irrigation, no temperature increase is needed to break production possibilities.

On the other hand, a combination of N fertilizer application plus one more irrigation just before the grain filling phase begin, could make possible to achieve a high yield production, nearly up to five tons per hectare.

Figure 4-10 The effect of an increasing weather temperature on flowering and maturity dates (above), as well as it has on grain yield and biomass production.





Previous commercial crops

Wheat

From the field trial mentioned above, in the Methods section, made during 2002-2003 wheat growing season, at Apodaca site of ITESM, genetic coefficients for three cultivars were calculated. Similar procedures than those explained for sorghum trial, were followed. Cultivars and the proposed coefficients values are shown in the table 4.3.

Table 4.3 Genetic coefficients proposed for three wheat cultivars.

@VAR#	VRNAME	ECO#	P1V	P1D	P5	G1	G2	G3	PHINT
IB1908	SONALIKA	IB0001	0.5	1.8	-0.0	540	2.0	1.7	95.00
IN0001	INIFAP	IB0001	0.5	1.8	-0.0	540	2.0	1.7	95.00
TM0001	CHOIX	IB0001	0.5	1.8	-1.5	600	3.0	1.7	95.00

Wheat was cultivated from 1990 to 1993 under irrigation and fertilization management practices. Figure 4-11 shows the simulated yield response of two wheat cultivars to 10 different levels of Nitrogen fertilization. According to that simulation results, an optimum point is reached at 52 kilograms of Nitrogen per hectare, for the simulated cultivars. Even though cultivar Sonalika had a point out of expected, the new INIFAP cultivar depicts a typical curve for a gramineae fertilizer response.

Simulated grain productions from both cultivars were higher than the one actually obtained with a different cultivar 10 years ago.

Figure 4-11 Grain yield response of two wheat cultivars to variation on fertilizer application.

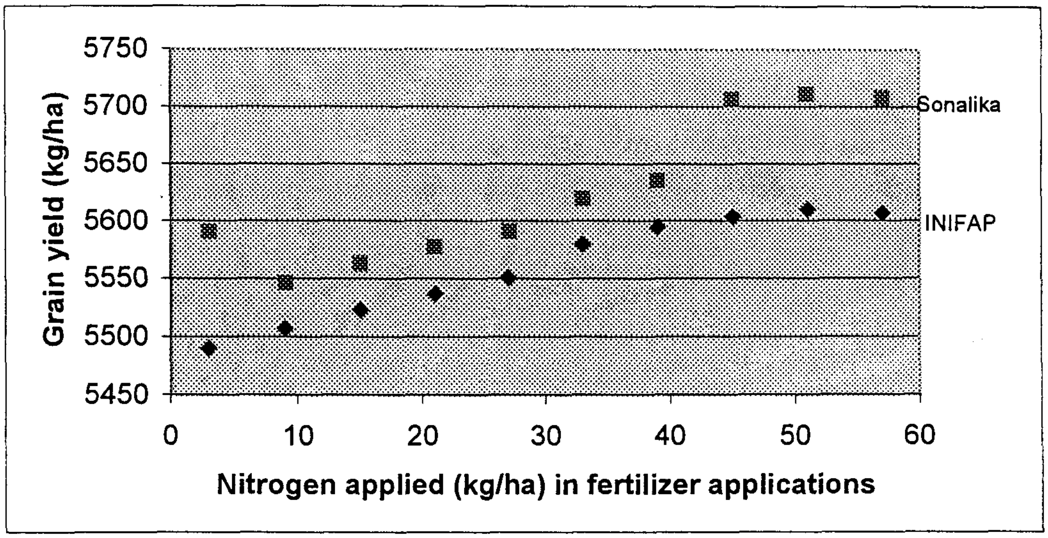
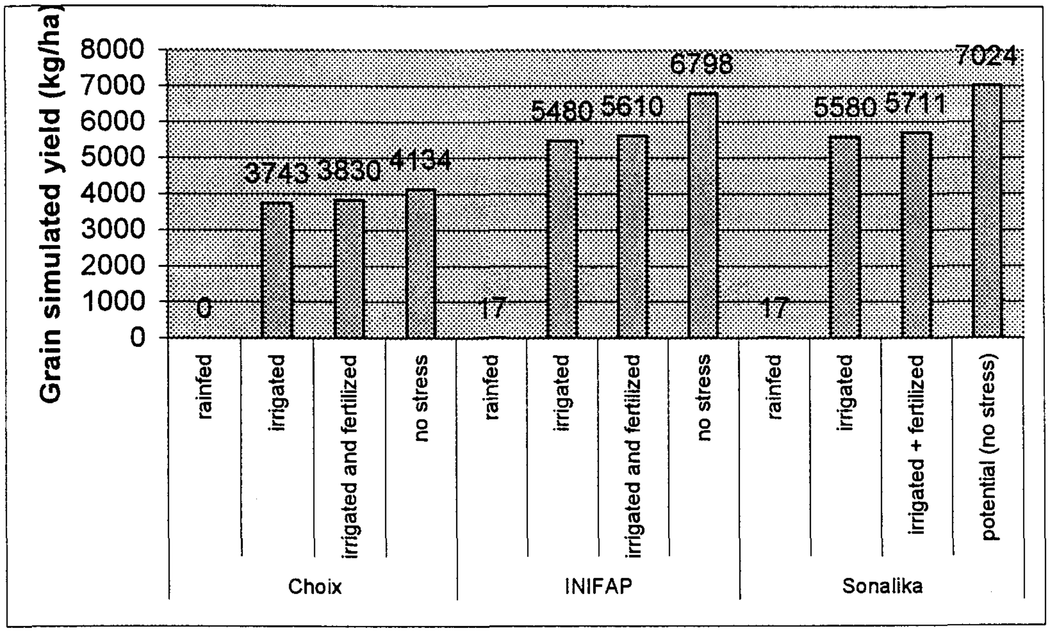


Figure 4-12 shows a comparison between three cultivars with four different water and fertilizer operation management decisions. Simulation exaggerates the lack of water effects on the results for rainfed situation. Yet, if it is true grain yield is not existent or zero, it is also true that it is too small for being an economical option, which it is the reason why wheat is not cultivated without irrigation in this part of Mexico. Irrigated and optimally fertilized, the cultivar Choix is the one that better comes closer the reality. Sonalika and INIFAP cultivars, however, have not been tried in Vaquerías; therefore, they could represent a very good alternative in case the genetic coefficients are correctly calculated. These cultivars simulated potential yield never seen at Northeastern Mexico, and similar to the ones they have at the wheat zone at Sonora state. It is also observed in that figure (4-12) the slight difference made by fertilizer applications for all three cultivars. That can explain the farmers' idea about considering fertilization as non-worthy of their effort.

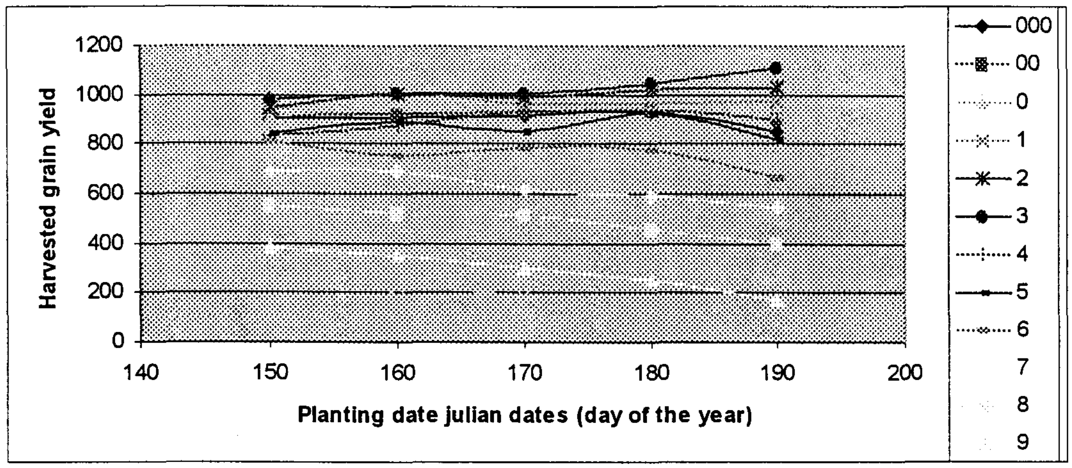
Figure 4-12 Simulated grain production of three wheat cultivars at Vaquerias site under for different fertilizer and water management conditions.



Soybean

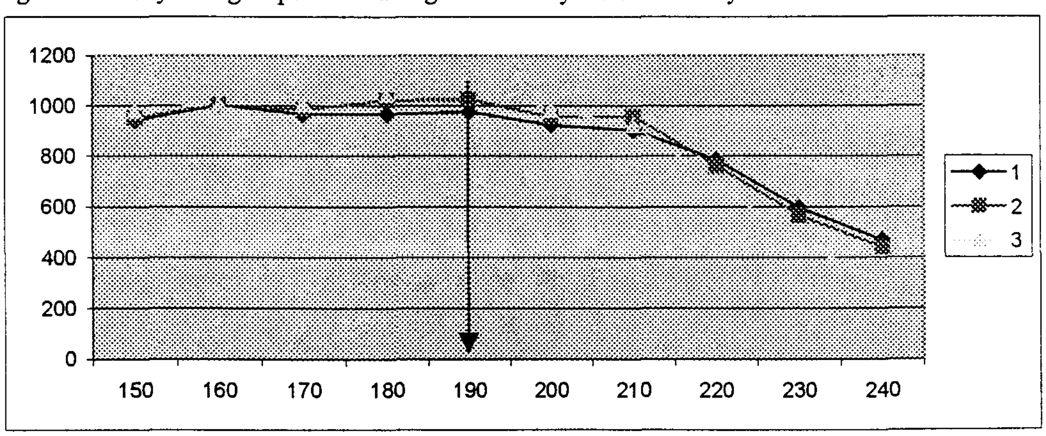
Soygro model, for soybean growth simulation, also includes general groups of genetic coefficients in its genotype file. Simulation was run using those general groups and changing the planting date. Figure 4-13 shows simulation results for grain yield.

Figure 4.13 Soybean groups behavior on different plantig dates.



Soybean is a summer crop for this region and its activity dates are to be in agreement with the ones of the winter crop, as can be wheat. After wheat harvest in may, best planting dates for soybean are those of June and early July. Soybean genotype groups 3, 2, and 1, followed by 0, 00, and 000 simulated the higher yields around julian day 190 (figure 4-14), but still low for the obtained average of more than 2 ton/ha up to 3 ton/ha. Simulation for this crop needs adjustment, probably with more recent soybean field data.

Figure 4-14 Soybean groups 1 –3 having maximum yield around day 190.

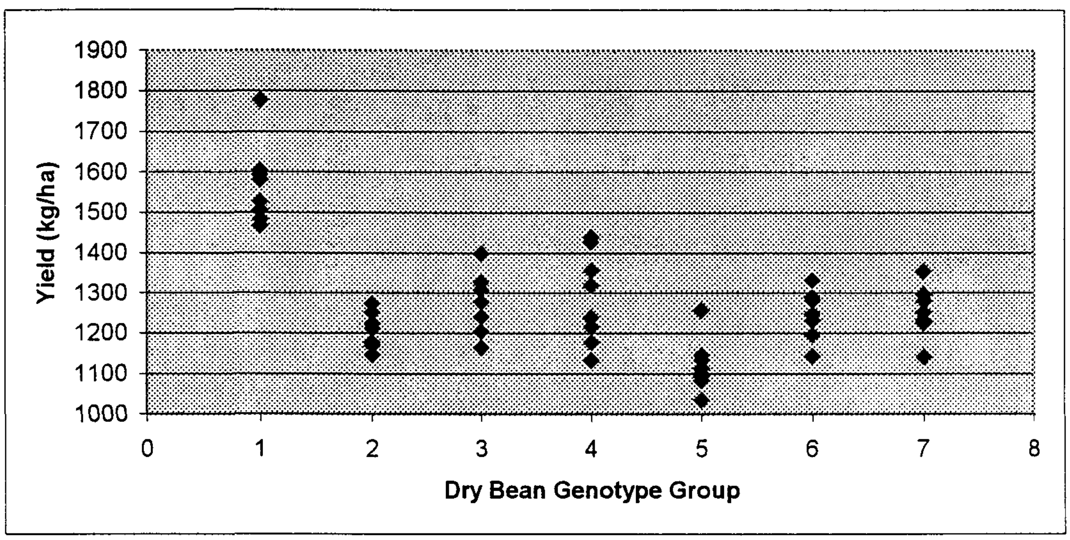


Other possible commercial crops (beans, potato)

Beans

The seven-genotype groups of the BEANGRO model were simulated with soil and weather from Vaquerias, varying planting dates. Results, depicted in figure 4-15, shows group 1 as the one with possible higher yield in all the five different planting dates. Interesting is the fact that group 1 is an Andean and not a MesoAmerican or a Mexican one. However, simulated yield remains/ed too low.

Figure 4-15 Dry bean genotype groups simulated under Vaquerias conditions.



Group 1 was simulated as managed with varying levels of Nitrogen fertilization. Results are shown in figure 4-16, depicting the typical quadratic equation for fertilizer respond, with a highest level at 120 kg of Nitrogen/ha and a yield of 3850 kg/ha. No higher yield was obtained with any other cultivars group,

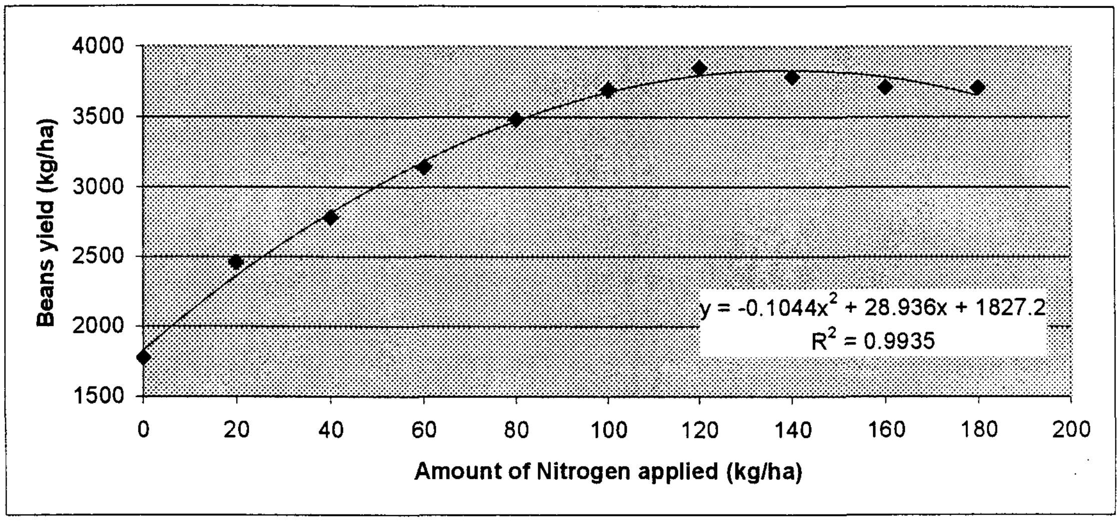
Summary and conclusions

According to simulation results, all simulated crops could be produced under Vaquerias conditions. Crops with well-known genetic coefficients calculated from field trials data, like sorghum and wheat, simulated yields close to field observed data. No observed yield exists for potato in Vaquerias. Yields simulated were lower than generally observed field data, for those crops with genetic coefficients approximated from generic groups. Genetic coefficient determination work is needed for Mexican cultivars of soybean and dry bean. Sensibility analysis showed the high dependence crops have on the irrigation availability in Vaquerias region. The high respond of beans (Leguminoseae) to fertilizer could imply that sorghum, wheat, and maize (Gramineae) could respond to different kinds of fertilizer.

Potato simulated a very low yield (just a third part of the total produced in the highlands), but the usual high prices could introduce it into the farm system plan. Not one of the simulated crops is to be eliminated out of plan. According to best planting dates, twelve crop combinations (rotations) will be proposed, including sorghum, wheat, potato and soybean for the first cycle; and sorghum, soybean, and dry bean, for the second cycle of the year.

planting date, N level, or combinations of them. Real yield data at Vaquerias are 1.5 ton/ha and 2.0 ton/ha under rainfed and irrigated conditions respectively, with a Mexican cultivar. Possible disease and pest affections have to be analyzed before try some of the Andean cultivars in the region.

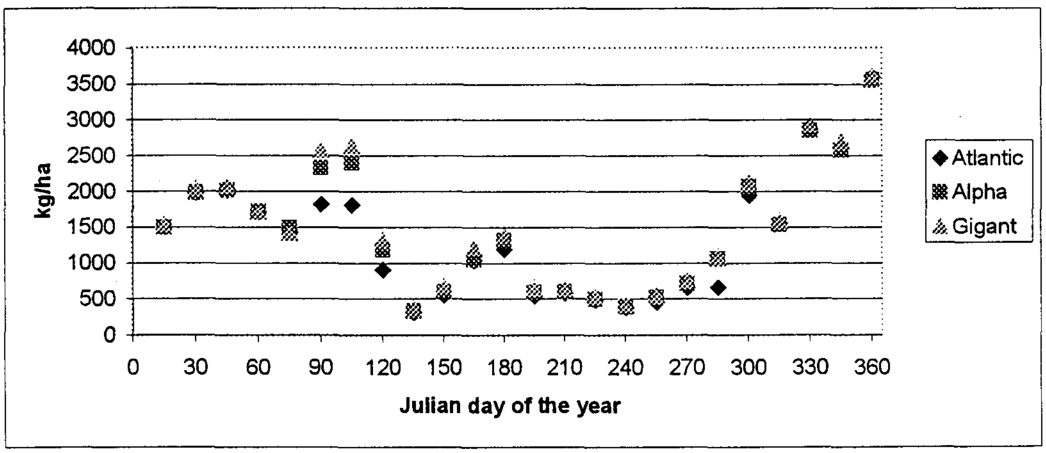
Figure 4-16. Dry bean Andean group 1 simulated response to N fertilizer under Vaquerias conditions.



Potato

Potato is the most profitable commercial crop in the State, but it is limited for the Highlands. Genetic coefficients calculated for Atlantic, Alpha and Gigant cultivars were taken from a previous trial and simulated under Vaquerias soil and weather conditions. Trying to establish the best planting date, the three cultivars were simulated in a rush of dates. Results, exposed in the figure 4.17, show a relative peak in April and definitive best dates during December.

Figure 4-17 Simulated potato yield along year to calculate planting dates



The yield obtained in the simulation had a range from 2.5 to 3.5 ton/ha in the mentioned dates. Major yields might be obtained by a more complete fertilization, but the resultant dates must compete with the sorghum, instead of complementing it.

CHAPTER 5

EVALUATION OF DIFFERENT STRATEGIES FOR EJIDO FARMS OF NORTHEASTERN MEXICO

Introduction

In chapter 3, the current Vaquerías communal farm agricultural system was described, including its sustenance options. A linear programming ethnographic model that describes with great accuracy what is happening in such a system was created. In this way, it adequately mimics its current reality, obtaining the same results as those decided by the farmers, given their circumstances. However, the fact that the model closely describes the communal farmers' decisions does not mean that they are making the best possible decisions.

In chapter 4, the possible performance of various crops was simulated under soil and climate conditions proper to the Vaquerías communal farm geography. Information from crops considered viable was used for various reasons, through dynamic models that simulated crop growth, like CROPGRO and CERES, contained in the Decision (Making) Support System known as DSSAT. This simulation allowed us to know the production potential of the simulated crops have for the zone being studied, during its optimal sowing season.

In this chapter, both tools will be used, the ELP as well as the models that simulate crop growth (crop growth simulation models), to obtain a series of possible scenarios that could help in the decision making process. These possible scenarios should improve the quality of the current decisions, seeking the optimal use of resources to yield the greatest possible amount of yearly income.

Objectives

The main objective of this chapter is to draw one or several strategies (understood as the chosen mix of economic activities) that would maximize the annual income of the typical Vaquerías farm system, considering the climate and market changes.

Methodology

General

Various possible climate scenarios for the conditions of Vaquerías will serve as an input to perform a sensitivity analysis of the climate and of the simulated crops. The information drawn from these simulations will feed the ELP model to obtain the activity combinations that would maximize the income for each scenario.

The different climate scenarios were created from a file calculated as the average of statistical normalized real information taken from three climate stations: "El Cuchillo" (China county), "Cerro Prieto" (Linares county), and "" (Gral. Terán county). Information was provided through the Internet by the National Water Commission (CAN) and the National Weather Service (SMN). Table 5-1 shows details.

Table 5-1. Years and internet site of weather stations

Station	Years	Internet site
El Realito	1961-1990	http://smn.cna.gob.mx/productos/normales/estacion/nl/NOR19019.TXT
Cerro Prieto	1961-1990	http://smn.cna.gob.mx/productos/normales/estacion/nl/NOR19011.TXT
El Cuchillo	1961-1990	http://smn.cna.gob.mx/productos/normales/estacion/nl/NOR19016.TXT

The simulation of crops was performed in the DSSAT, which allowed to run the simulation models (CERES and CROPGRO) in consecutive seasons and/or individual, to perform a "sequential analysis" in the most adequate fashion and thus observe the simulated results in the long term. In this way, although the ELP model is static, it feeds from the data obtained in a dynamic fashion and in the long term so that the decision does not limit to the moment, but considers the possible future and can have a greater probability of being sustainable.

Experimental design for simulation

Treatments or experimental runs to be simulated in the ELP model are the different crop combinations that the farmers can choose. The crops that form these combinations were selected according to the results obtained in the previous chapter (4), where a range of planting dates was drawn for each crop, in which such crops showed possibilities of offering an acceptable production. All twelve combinations mentioned in chapter four are shown in table 5-2.

Table 5-2. Crop combinations (rotations) considered as treatments

Rotation number	First semester	Second semester
1	Sorghum	Sorghum
2	Sorghum	Soybean
3	Sorghum	Dry bean
4	Wheat	Sorghum
5	Wheat	Soybean
6	Wheat	Dry bean
7	Potato	Sorghum
8	Potato	Soybean
9	Potato	Dry bean
10	Soybean	Sorghum
11	Soybean	Soybean
12	Soybean	Dry bean

Because the models that simulate the crop growth (crop simulation models) are deterministic, the order of the experimental runs is not important, nor the sense in performing repetitions due to the fact that the result would always be the same. However, with the objective that the result did not consist in "the best decision for the previous year", but that it obtained one or various sufficiently robust combinations to resist both the climate problems as well as the market conditions, it relied on the practice of making repetitions of the experimental runs, under different environmental circumstances; specifically related to temperature, rainfall and prices.

Being 12 crop combinations those that were to be tested in at least three levels (low, medium and high) of each environmental characteristic, 324 possible combinations (12*27) were available. Hence, it was decided to rely on the theory of fractioned designs and concretely to G Taguchi's "the noise signal" theory to reduce the number of simulations to 108 (12*9). The design is shown in figure 5.1. The variable measured, - or calculated in this case -, and evaluated in the design, is not production, but the annual net family input.

Fig. 5.1. Experimental design with 12 runs and 9 repetitions simulating the rotations of the crops in three different levels of three environmental factors. 108 total inputs.

				1	2	3	4	5	6	7	8	9
			Temp	1	1	1	2	2	2	3	3	3
			Prec.	1	2	3	1	2	3	1	2	3
			Precio	1	2	3	3	1	2	2	3	1
	ROTACIONES											
1	Sorghum	Sorghum										
2	Sorghum	Soybean										
3	Sorghum	Dry bean										
4	Wheat	Sorghum										
5	Wheat	Soybean										
6	Wheat	Dry bean										
7	Potato	Sorghum										
8	Potato	Soybean										
9	Potato	Dry bean										
10	Soybean	Sorghum										
11	Soybean	Soybean										
12	Soybean	Dry bean										

Actually each one of the 108 inputs is the result of having simulated two crops, each one in its respective farming station and with the corresponding climate to the repetition, to obtain the production and, subsequently, run the ELP model with the resulting production information and the adequate level of prices. There are three simulations in each input.

The environmental variations are indispensable so that the result can have some possibility of future success. The sequential analysis tool provided by the DSSAT was not used because the result had to be known for each condition and not only the final consequence. Moreover, the inclusion of prices had to be done in the ELP model, which contemplates all the characteristics for each farm level and not only for the field level.

Environmental Factors (noise)

Temperature

Three temperature levels were taken into account. From a monthly average file, calculated for the zone with the use of similar files that recount information for 29 years (1961 –1990) for the mentioned three surrounding stations, three climate files were generated: one with the diminished daily temperature (maximum and minimum) (TMVF0301.wth) which represents level one. Another was set with the maximum and minimum temperatures of each day augmented (TMVC0301.wth), which constitutes the level three, and a third that represents level two, that is covered with the average temperature file (TMVA0301.wth). All the files are included in annex 5.1. The amount of degrees celsius to be increased or decreased was calculated according to the dispersion presented by the mean temperature of each month. The difference presented in the average mean daily temperature with the second and fourth percentile was translated to maximum and minimum temperatures to generate the monthly averages of "cold" or "hot" years. Table 5-3 shows the monthly temperatures used. With those monthly averages the climate was simulated for all year long.

Table 5-3. Monthly temperatures used for simulation of "cold" and "hot" years

	MAXIMUM TEMPERATURE		MEDIUM TEMPERATURE	MINIMUM TEMPERATURE	
	"HOT" YEAR	"COLD" YEAR	NORMAL STANDARD	"HOT" YEAR	"COLD" YEAR
ENE	23.4	16.6	13.3	10.4	3.7
FEB	25.7	20.2	15.8	11.3	5.9
MAR	30.3	24.8	20.2	15.0	9.5
ABR	34.1	29.6	24.3	19.4	14.9
MAY	35.8	31.4	26.9	22.3	17.8
JUN	37.8	33.3	28.6	23.8	19.3
JUL	38.4	34.1	29.2	24.1	19.8
AGO	38.2	33.1	28.9	24.0	18.8
SEP	35.1	30.8	26.8	22.3	18.1
OCT	31.7	26.3	22.7	18.8	13.4
NOV	28.0	21.9	18.6	15.0	8.9
DIC	24.3	17.4	14.9	11.2	4.3

The temperature factor levels were captured in different files, showed in table 5-4.

Table 5-4. Weather files with temperature changes.

Level	Change	File
1	"COLD" YEAR	TMVF0301.wth
2	AVERAGE YEAR	TMVA0301.wth
3	"HOT" YEAR	TMVC0301.wth

Precipitation

Trying to emulate rainy and dry years, three levels of precipitation were included. Considering the same files of 29 years of rain in three surrounding stations, a calculation of the zone normal standard distribution was obtained for each month. The mean of this distribution represents the monthly rain of a previous year. This is the second level of precipitation, registered in the TMVA0301.wth base climate file. The second quintile of this distribution represents the monthly rain of a dry year; this is the first level of precipitation, registered in the TMVS0301.wth. base climate file. The fourth quintile of this distribution represents the monthly rain of a dry year; this is the first level of precipitation, registered in the TMVH0301.wth. base climate file. Given the fact that crops are produced using irrigation, the first level of the precipitation factor includes the low rain file (dry year) and an irrigation decrease, assuming that the dam does not have enough water for all irrigation. The "rainy" year receives the same amount of irrigation than the average year, but with the savings of the cost of irrigation.

Table 5-5. Weather files with precipitation changes.

Level	Change	File
1	2° Percentile	TMVS0301.wth
2	Average	TMVA0301.wth
3	4° Percentile	TMVH0301.wth

Each simulated experimental run has a certain temperature level and a certain level of humidity. Thus, the files should be combined for their proper functioning, or use those of one factor and correct the other in the sensitivity analysis option.

Price

It is expected that the prices suffer fluctuations in the ensuing years. Once the production is simulated, the decision to opt for a certain crop in a cycle or a certain rotation in the year should compete with the rest of the crops and their combinations. The complete ELP model (the two yearly cycles) tripled to obtain years of average, high and low prices. The variation of these prices was calculated for each product based on the long term projections expected for the USA and Mexico in the coming years, according to the report (Aserca, 2004). As a matter of fact, the year 2003 had high prices.

ELP model adaptation

As expected, the linear programming model was modified in order to simulate the probable production of the evaluated crops rotations. In appendix 5, a picture of the original model is shown and appendix 6 depicts in indicates in shadow the incorporation of the production and sales activities of the afore-mentioned crops, indicating production quantities (coming from the "crop simulation models") and the sales prices.

Analysis

An analysis of means, in order to identify the optimal combination, was performed on the results to select the strategies that, in the next chapter will be presented to the farmers for their consideration.

Results

Figure 5-2 shows the production results found in the different combinations. In table 5-6 the economic results gathered by the different crop rotation are presented, under the selected circumstances of noise effect, including the different levels of temperature, precipitation and price.

Figure 5-2 Production results (dry matter per hectare) found in the different combinations

Temp	1		1		1		2		2		2		3		3		3	
Prec.	1		2		3		1		2		3		1		2		3	
Precio	1		2		3		3		1		2		2		3		1	
ROTATIONS																		
SG SG	2534	4119	2398	4134	3882	4012	3776	3703	3882	4012	3882	4012	3776	3703	3882	4012	3882	4012
SG SB	2534	1454	2398	1256	3882	803	3776	1367	3882	1385	3882	985	3776	1453	3882	912	3882	818
SG DB	2534	2221	2398	2071	3882	2141	3776	1829	3882	1868	3882	1596	3776	1757	3882	1422	3882	1276
WH SG	2281	4119	6284	4134	4529	4012	3213	3703	3750	4012	4529	4012	2514	3703	4788	4012	4529	4012
WH SB	2281	1454	6284	1256	4529	803	3213	1367	3750	1385	4529	985	2514	1453	4788	912	4529	818
WH DB	2281	2221	6284	2071	4529	2141	3213	1829	3750	1868	4529	1596	2514	1757	4788	1422	4529	1276
potato SG	1710	4119	3575	4134	2220	4012	6310	3703	4750	4012	2665	4012	4540	3703	7055	4012	2030	4012
potato SB	1710	1454	3575	1256	2220	803	6310	1367	4750	1385	2665	985	4540	1453	7055	912	2030	818
potato DB	1710	2221	3575	2071	2220	2141	6310	1829	4750	1868	2665	1596	4540	1757	7055	1422	2030	1276
SB SG	1107	4119	978	4134	1141	4012	948	3703	1303	4012	1115	4012	868	3703	1041	4012	1095	4012
SB SB	1107	1454	978	1256	1141	803	948	1367	1303	1385	1115	985	868	1453	1041	912	1095	818
SB DB	1107	2221	978	2071	1141	2141	948	1829	1303	1868	1115	1596	868	1757	1041	1422	1095	1276

Production is presented in dry matter per hectare, as founded for each simulated combination. Each column per production cycle for each combination. Cases reported zero, failed to produce under simulated conditions. SG = sorghum; WH = wheat; SB = soybean; DB = dry bean.

Table 5-6. Net annual family income in Mexican pesos as results of farming system using proposed crop rotations.

Temp		1	1	1	2	2	2	3	3	3
Prec.		1	2	3	1	2	3	1	2	3
Precio		1	2	3	3	1	2	2	3	1
ROTACIONES										
SG	SG	97,586	107,433	142,185	137,055	107,541	120,353	116,026	142,185	107,541
SG	SB	76,753	87,360	116,253	115,016	87,671	101,560	100,478	116,253	87,671
SG	DB	126,068	136,282	174,762	156,773	121,823	127,527	134,226	136,357	97,711
WH	SG	90,303	101,079	118,960	115,066	89,340	99,799	96,554	118,960	89,340
WH	SB	69,470	81,006	93,027	93,027	69,470	81,006	81,006	93,027	69,470
WH	DB	118,786	129,928	151,537	134,784	103,622	106,973	114,753	113,132	79,510
potato	SG	90,303	101,079	118,960	115,066	89,340	99,799	96,554	118,960	89,340
potato	SB	69,470	81,006	93,027	93,027	69,470	81,006	81,006	93,027	69,470
potato	DB	118,786	129,928	151,537	134,784	103,622	106,973	114,753	113,132	79,510
SB	SG	90,303	101,079	118,960	115,066	89,340	99,799	96,554	118,960	89,340
SB	SB	69,470	81,006	93,027	93,027	69,470	81,006	81,006	93,027	69,470
SB	DB	118,786	129,928	151,537	134,784	103,622	106,973	114,753	113,132	79,510

In table 5-7 the final results can be observed, sorted according to annual income.

Table 5.7 Economic results (Mexican pesos) sorted from higher income. Annual net income data, calculated from the simulations.

	ROTACIONES		media	rango	var	min
3	SG	DB	134,614	77,051	21,672	97,711
1	SG	SG	119,767	44,599	16,813	97,586
6	WH	DB	117,003	72,027	20,568	79,510
12	SB	DB	117,003	72,027	20,568	79,510
9	potato	DB	117,003	72,027	20,568	79,510
4	WH	SG	102,156	29,620	12,442	89,340
7	potato	SG	102,156	29,620	12,442	89,340
10	SB	SG	102,156	29,620	12,442	89,340
2	SG	SB	98,779	39,500	14,779	76,753
5	WH	SB	81,168	23,557	10,201	69,470
8	potato	SB	81,168	23,557	10,201	69,470
11	SB	SB	81,168	23,557	10,201	69,470

Economic results showed in tables 5-6 and 5-7 are not only crop income, but family income gained with all enterprises and livelihood combination that the entire household is able to achieve.

Sorghum in the two cycles is the today's real chosen rotation. The only option that supersedes the current system is rotation number three, which includes beans in the second cycle and presents better economic possibilities, as it is possible to appreciate in table 5-7. Dry bean is presented in the second cycle of four out of the five best rotations, given the price shown by this product. Likewise, beans have a cushion effect on the variations presented by the rest of the crops, especially because beans are always sowed for self-consumption, even when its temporal.

Likewise, table 5.7 shows that soybean in the second cycle presents the least satisfactory options. Add to that the perspectives that the soybean prices tend to decrease as a result of the increment in imports.

The main combination to be proposed is sorghum – bean, that presents many advantages, including the producers' familiarity, and that they feel comfortable with these crops.

CHAPTER 6

DECISION CRITERIA

Introduction

In the previous chapter, a series of possible decision combinations were obtained in order to maximize the annual family income using dynamic simulation systems for crops and the Ethnographic Linear Programming Model, specifically created to map this community. This chapter seeks to compare these options – theoretically optimal – with decisions made by farmers and analyze the probable discrepancies in order to identify the main factors involved in the farmers' decision making process. In this way, a better understanding of the process is being sought in order to offer a better support.

While many authors (K. J. Boote et al., 1998; T. Hodges, S. L. Johnson, & B. S. Johnson, 1992; J. W. Jones et al., 1989; B. Kaya et al., 2000; H. Lal et al., 1993; E. Matthaeus, W. Mirschel, H. Kretschmer, K. Kuenkel, & I. Klank, 1986; F. W. T. Penning De Vries & H. H. Van Laar, 1982; H. Salinas, R. G. Ramirez, & A. Rumayor-Rodriguez, 1999; J. J. Stoorvogel, 1995) acknowledge the use and advantages of the models that simulate dynamic systems specifically applied to cattle and crops, they also consider these models to be limited and insufficient regarding the complex reality that the decision maker has to face about an agricultural system. The reality is that these models, scientifically sound, are not used by the decision makers or their advisors. Probably a simple ignorance of their existence (which would show a poorly trained technical assistance), or a questioning about its validity, or doubts about the possible technical application, could be the reasonswhy they are not being used. Models that simulate crop growth, for example, are excellent tools that are not being used and it is worth the effort to investigate the reasons for that.

The truth is that even when these dynamic models are used to support the decision making process, several decision making criteria will be left without being considered. Historically, the farmer has worried about the decisions affecting their crop yield and thus, their decisions are guided by their concern of producing enough volume, being for family consumption or for the market. The production amounts, or production criterion, can be adequately simulated by the current models. As a matter of fact, some issues regarding environmental sustainability, those referred to the conservation of natural resources such as soil and water, can be successfully treated with these models. Unfortunately, the decision makers do not know this. The economic and financial criteria, as well as the quality issue, have not been sufficiently developed in the DSS which include dynamic simulation models.

Nowadays, the farmer lives in a new environment which compels him to cease to be a peasant that produces his own food in order to convert him into a successful farmer, and the manager of a firm of agricultural enterprises, that goes through the production criterion and sets himself into the economic and financial profitability criteria. These criteria have been treated with greater success by the agricultural economists through

Linear Programming static models. Although these models are not new (they have more than half a century of existence), their use has been limited to the academic institutions and have not managed to significantly impact the agricultural business community. Perhaps the cause that these models have not been used, lies in the critics made to its reputation as a stiff tool, full of ideal assumptions not likely to occur, which turns it into a theoretical and not so realistic tool. However, on the other hand, its modern focus is probably ignored, including the huge computer ease that simplify its use, unlike half a century ago.

However, even when we achieve a convenient use of the dynamic simulation models, -that use physical and chemical variable factors to simulate the development and behavior of cattle, crops and environmet-, and add the adequate use of the linear programming models, that does not limit to the traditional resources of soil, labor and capital, but has managed to incorporate restrictions from endogenous factors, like family structure and needs, and also some constraints from exogenous factors, like market and financing availability, the results obtained do not reflect the decisions really made by the farmers. An easy exit is to consider that the models are normative and the farmers are wrong when they don't choosethe "solution" provided. Nevertheless, it will be much more enriching when trying to investigate the reason for the difference. This way, we could learn more about the real system, to offer an even more adequate support for their decisions.

Literature Review

Salinas et al (1999), presented an example of the use of linear programming with research purposes applied on a goat producing system in Mexico. Their work shows various tool limitations when it limits to the production and the decisions of the producers are limited to those suggested by the researchers. Moreover, the same tool favors the producers when it reveals that the traditional technology –preferred by them-, is more "robust" with regard to price fluctuations. Thus, the risk aversion and betting for the traditional attitude resulted in a better strategy than the input maximization. It is difficult to believe that the producers did not wish to maximize their revenues, but in this case the proposed technology did not consider important aspects for the producers.

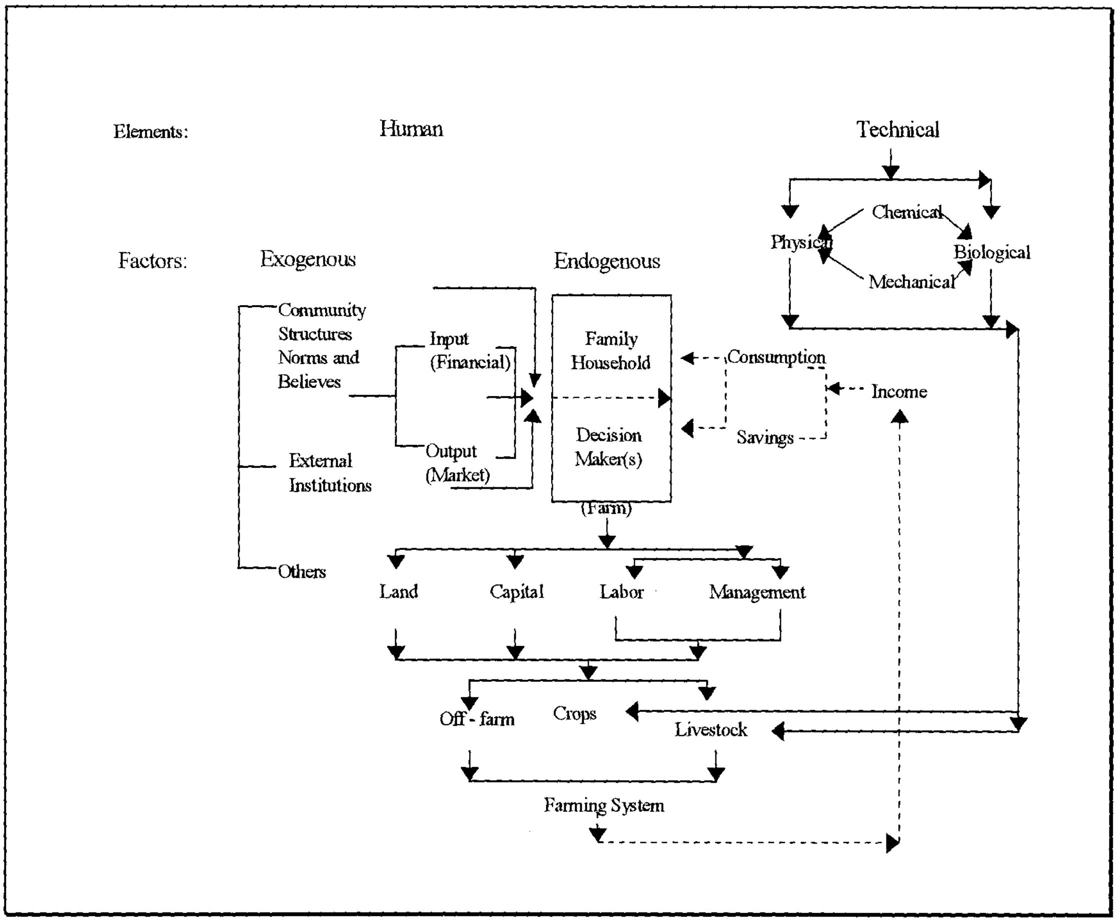
Thangata, et al (2002) on their part, show a linear programming model with an ethnographic focus (ELP), that helps to analyze the decision making process in a village in Malawi, regarding the adoption of agroforest technology. The adaptation of the tool allows the proper evaluation of the proposed technology, from the affected family's standpoint, and not only technically. This different perception regarding the importance, uncertainty and controlability of the various factors, has been tried to be studied lately, with different approaches. Van Tassel and Keller (1991) published a study made in Tennessee, U.S.A. In this research, they try to determine the importance, uncertainty and controlability order so that the farmers have nine factors previously identified as the key in the decision making process. These factors are: farm inputs, borrowing money, hiring labor, market outlets, competitors, government farm programs, public attitudes toward agriculture, advances in technology and environmental issues. All these factors can affect the decision to make and not necessarily are included in the simulation model.

It has been always considered that the models are about to simulate the possible behavior of the systems and subsystems under certain circumstances and, once the possible response is known, the decision will correspond to the decision maker who will take into account the information provided by the model, as well as the additional information he can possess. This is good, logical and respectful, but not very useful for the policymaker, who does not have any idea of the decisions the farmers will make nor, consequently, of the effect of the policies adopted. Understanding this decision-making process is really important and, according to Olmer (1998), few studies have been made about how farmers make decisions.

Norman (1986), when defining the Farming System, provides us with an excellent system model, which allows us to visualize a complex decision-making panorama, with the farmer at the center, trying not to lose control, while the issue is still riding under uncertainty. Norman groups the complete system under two elements: the human and the technical element. The latter is formed by physical – chemical factors that determine the behavior of production biological entities, like cattle and crops. The human element has exogenous factors to the farm and endogenous to it. Among the exogenous factors are the community structure in terms of cultures and beliefs, as well as the financial and corporate institutions. The existence of a market for farm products provides an exit for it.

Likewise, the availability of financing and operation inputs provide an entry, but mainly are part of society's influences over the decision making process. Within the endogenous factors, at the center of the model, lies firmly the decision maker with all his family weight over him, both for his participation in the decisions, as well as for his physical and non-physical needs that should be satisfied. The decision maker relies on capital, soil, information, labor and a management style resources. After all, "Management has been commonly referred as the decision-making process" (L. W. Van Tassell & L. H. Keller, 1991). The manager then decides the resource allocation quantity, quality and opportunity wise, to the animal and vegetable production systems, as well as their relationship to the natural environment, to create their own agricultural system. The result obtained should allow him to sustain his family and save for the future. If he does not comply this, he will be forced to change his decisions and apply in a different way his resources. Nevertheless, if he manages to comply, he will receive a strong positive encouragement to continue to decide in the same way, over something that he knows will work in the midst of uncertainty. The Norman model can be seen on Figure 6-1.

Figure 6-1. Defining a Farming System (D. W. Norman, 1986).



Objectives

In the work reported in this chapter, the options proposed by the ELP model are to be compared, with the decisions really made by the farmers; analyzing the possible discrepancies in order to identify the main factors involved in the farmers' decision making process, as well as the possible reasons for the lack of use of these tools.

Methods

The computer results were presented to the farmers in a group activity, asking them to fill up a questionnaire with their family information and decisions to be made. Subsequently, during personal interviews, these people were asked about the reasons to decide what was selected. A further analysis of the variables involved relates those of interest.

Following the participatory methods used by Bastidas (2001), a group activity was intended to show computer model results and ask for a survey to be completed. Since no one in the community completed the elementary school education, both community and researcher were not appropriately prepared for participatory tools usage. Group activity was used only to show computer model results. After that, personal interviews took place within long and deep conversations, face to face with all and each one of the available people in the community. A guided conversation script helped to complete the survey. Survey used by the researcher to register data is available in appendix 6-1.

An analysis of the main components was being planned for the results, but no statistical analysis was required, due to the small size of the sample and the obvious results obtained. In its place, a frequency analysis helped in the interpretation of the results.

Results

Fed with the resulting data from the crop simulation models (showed in table 5-5 of chapter 5), the ELP model simulated the typical household situation of a Vaquerías farm and indicated that, with the exception of the combination of double sorghum; that is, of cultivating sorghum on both semesters of the year, the rotations that would include beans in the second cycle are those promoting more family annual income (results are showed in table 5-7 of chapter 5). The rotation that maximizes income, given the restrictions of the community, is the sorghum – bean rotation. This indicates the farming under commercial crop irrigation, but among the productive activities, it includes corn for family consumption and the feeding of a minimum of 22 hens that provide poultry and eggs. Furthermore, it is recommended that several bean hectares remain without irrigation, if possible. The second recommended combination is sorghum – sorghum.

All 27 farmers who answered the interview-inquiery produce sorghum in both cycles, regarding their commercial crop. This is interesting in various ways. First, in the fact that all yield is? the same cultivar; second, that all of them separate their irrigated farming as their commercial activity from the rest of their activities and lastly, that their decision coincides with the second best combination proposed by the model. Maybe the reasons to choose this combination are different, but they coincide with the results of a rational model.

Figure 6-2 shows a Pareto diagram with the responses frequency of an alternate sorghum crop. The response “anything already farmed” is quite illustrative. As a matter of fact, bean and soy, which occupy responses 3 and 4, were already cultivated in the communal farm. Thus, it is possible that some were thinking in these crops; or these were chosen because they were already farmed and its behavior is already known. There was just one person who answered “potato” as his alternative crop.

Figure 6-2. Response to the question What would you farm other than sorghum?

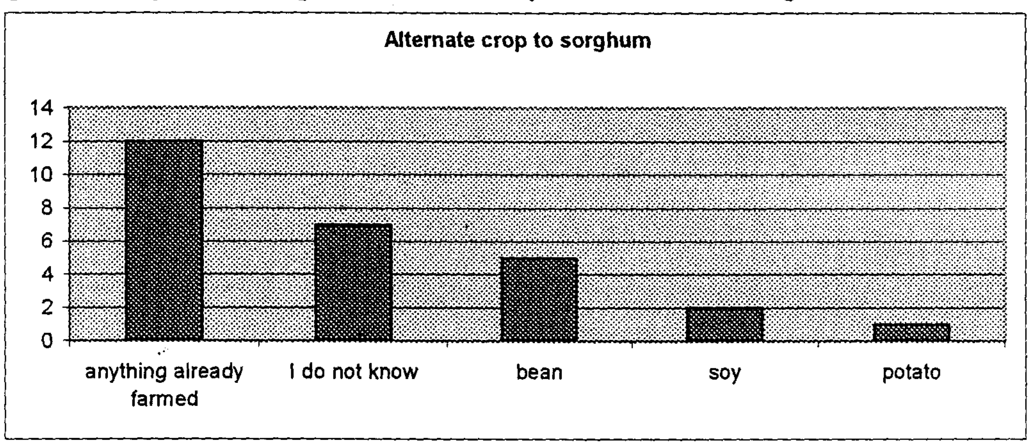


Table 6-1 shows the frequency of response to the question as to why sorghum was chosen to be cultivated. It can be noticed a great amount of options not chosen, while the “q” and “u” options had the greatest frequency. Option “q”, the one with greatest frequency, means that they responded “we chose sorghum because it is the crop we best know”. This coincides totally with the previous response and figure 6-2.

Option "u" corresponds to a response "because it is safer", which is congruent with a crop which is widely known and thus they know what to expect from it.

Table 6-1. Response frequency as to why sorghum was chosen as a crop.

Option	Answer sense	Frecuency	Percent
C	More money Higher profit	2	6%
K	Easier to sell	3	9%
M	Most people plant it in the community	4	12%
Q	The crop we best know	7	21%
R	It has good yield in here	4	12%
S	Because it give us two crops wit one planting	3	9%
T	It requier not so much work	4	12%
U	Because it is safer	6	18%

It is interesting that the options previously prepared included up to option "p" (Technology) and that the rest were added when these responses were received. This same question, sorting the responses by frequency, results very revealing and it is presented in table 6-2.

Table 6-2. Sorted answers to the question: why sorghum was chosen as a crop?

Answer	Frecuency
Because this is what we know.	7
Because it is safer.	6
Because this is what we know grows here.	4
Because this is what the majority farms.	4
Because not too much work is required.	4
Because it gives me two cuts.	3
Because this is a product with easy access to the market.	3
Because it yields more profits.	2

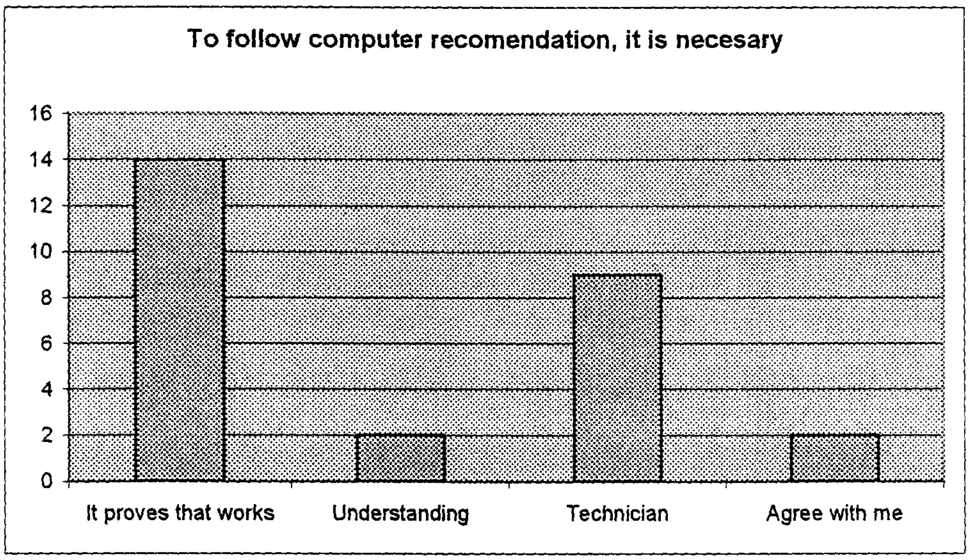
Majority, 21 out of 27, chose security. This is an expression of the feeling of uncertainty in which they make their decisions. Seven opted for the ease to obtain results and only five for typical elements of a rational analysis included in a model like the LP.

From here it is possible to identify the presence of elements that influence the decision making process and that can seem not rational, but either the fact of feeling confident in an environment of uncertainty as well as wanting to take advantage of time and effort, are rational positions and totally subject to be modeled.

Next point (4) in the questionarie is about reasons to change commercial crop. It has various questions related between them and with the recommendation of another crop. As a communal farm, Vaquerías was for many years dependant on a bank – government loan that was conditioned to the farming of certain crops. Now the communal farm has obtained a credit through a parafinancing institution that takes care of its interests through constant advising. It is possible that the current former farmers transfer their dependency to this entity and follow its guidelines. However, the response was a resounding 100% "NO." "Already was tried," that was I told??. "He wants us to produce forage because he is a livestock farmer, but we have not wanted." The partners, the technician and even the computer had better luck, although all of them received a "It Depends." The engineers and technicians have an excellent reputation, despite some unsatisfactory relationships. The "it depends" refers to the technician. Something similar happens with the partners. Some of them, between 5 and 8, are recognized by the community, who is willing to imitate them… but not in everything, since they have a reputation of hard work and not all of the community is willing to work a lot. Lastly, the computer is a perfect stranger. The "it depends" refers to the fact that if the program and the computer are good, but they do not have a way of knowing it.

All of them answered they knew about computers, but not knowing how to use them. They know that in the communal farm elementary school there is a computer and in the engineer's office too, but they do not know what to do with them. Regarding the fact that the computer can calculate the profits was not alien to them, but their responses shed some attitude. Responses like "I too can calculate them," "Yes, but they do not know other things" and "Those things are personal," show the intimacy of the topic and the fact that they are not willing to share personal information. To follow the recommendation of a computer program it is not enough that it comes from a computer. What they ask is that such a program or their recommendation demonstrate its use, in the practice, and in its circumstances. This can be observed in figure 6-3.

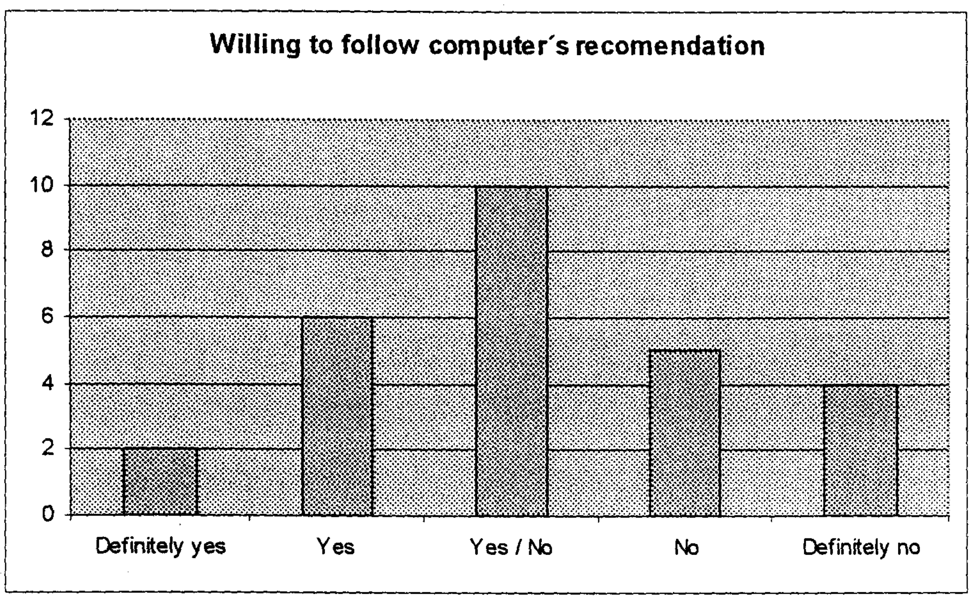
Figure 6-3 Response frequence to the requisite for believing in the computer program.



Even after seeing the model demonstration and being sure its own situation is being emulated, following the recommendation does not depend on the model, but on the recommendation itself... and on its success with others.

Lastly, once the model is run and the result demonstrated ("computer model's" recommendation to plant dry bean as commercial crop), the opinions were distributed according to the graph in figure 6-4.

Figure 6-4 Frequency acceptance distribution to the computer result.



The graph practically shows a normal distribution, although the sample is quite small. The great majority (central column) are undecided, while in the extremes there are 2 persons willing to accept the computer result and farm bean in the second cycle. In the other extreme there are 4 persons that say that definitely they will not follow the recommendation of rotating sorghum with beans giving three reasons:

a) "Requires too much work" (related with the difficulty of hiring and paying Labor).

b) "The bean farming is quite delicate to plagues and diseases" (related with the attitude of looking for free time).

c) "Who will buy it?" (related with the product launch into the market).

Among the reasons expressed to make the crop decision, none of the 9 factors identified by van Tassell were mentioned (1991). Hiring labor and market outlets were mentioned as the factors sufficiently important to determine not to follow the recommendation provided by the computer model. The rest of the factors were not mentioned in any question. The sorghum is a crop used in a semi-desert zone for its tolerance to drought. This would explain the decision for this crop before enabling the irrigation system, but a change would be expected with the technological adaptation. The technological progress was not mentioned and clearly it has not influenced sufficiently to change the crop. When it is brought up to the rest of the communal farmers, more than competitors, they are viewed as adventure partners. Moreover, when the issue of quality is brought up, they are clearly no decisions nor actions intentionally directed to this point and when asking for the environmental issues I even got smiles in return.

The environmental factors are more of a real and perceived importance. The fact that they are not currently considered for the decision making process does not express a lack of importance, but it sketches the empty space between what it is and what it should be; between what is known and what is done. It expresses ignorance, both from the relevance of the topic as well as the actions consequently adecuate. It can also express priorities to have solved their primary need before to think in – what they can be considering - the luxury long run.

Discussion.

Dr. J. B. Dent, after recognizing and weighing the place and use of the dynamic simulation models in the modern research of agricultural systems (Dent & Thornton, 1988), proposes to go beyond them to help in the decision making process, incorporating economic and ecological models (Dent, 1995). More than a model, Dent's proposition is the sequential use of independent models, according to what can be observed in figure 6-5. In certain way, this work followed this idea of using models sequentially (first the crop simulation models and later the ELP model), except for the lack of the ecological integration. Although it is a good proposition that uses what is already in existence, a general model would be more realistic and according to the trend expressed by Norman (2002) on figure 6-6.

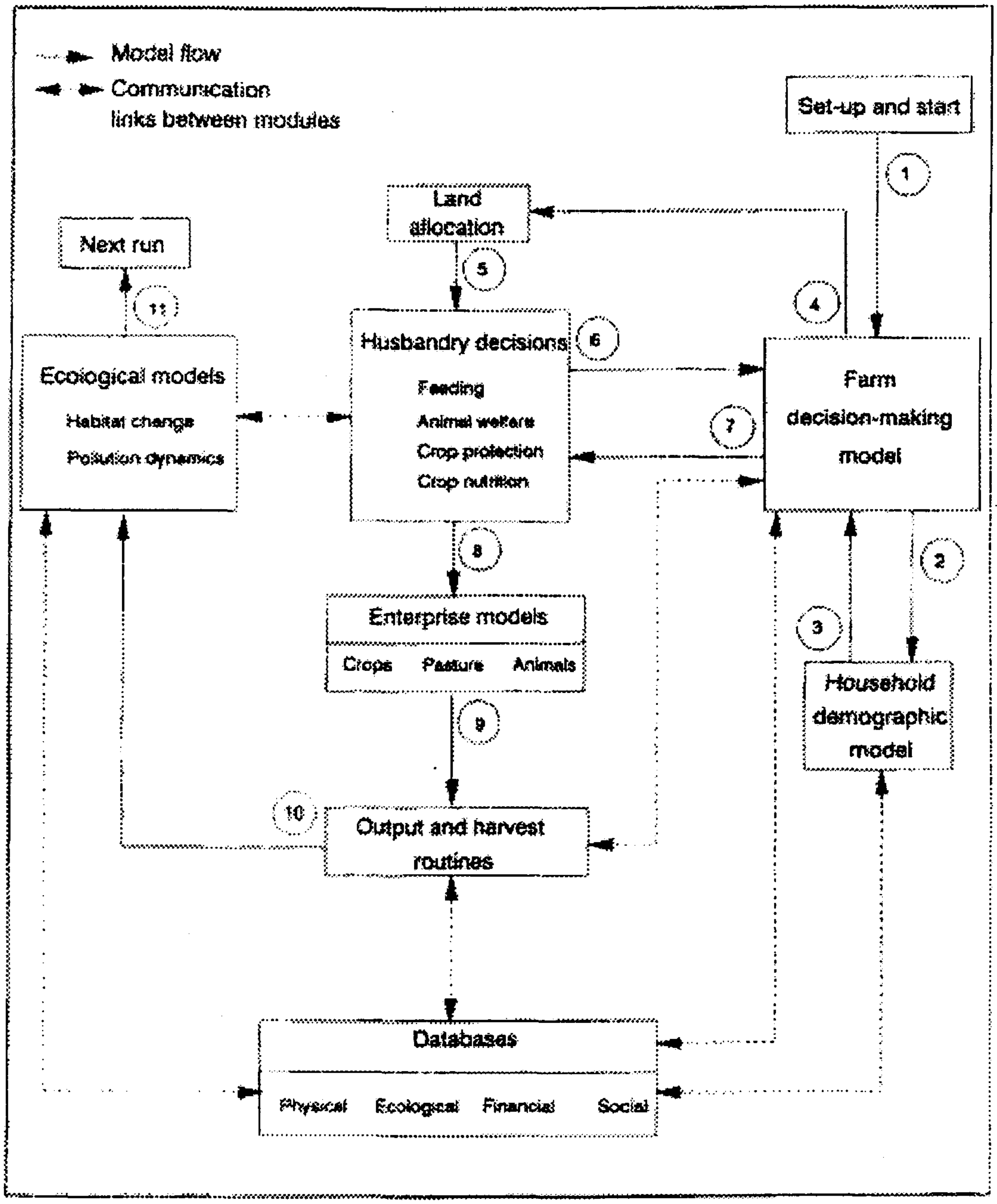


Figure 6-5. Structure of a conceptual whole farm model incorporating agricultural, social and ecological components. The sequence of model flow is indicated by numbers adjacent to solid arrows.

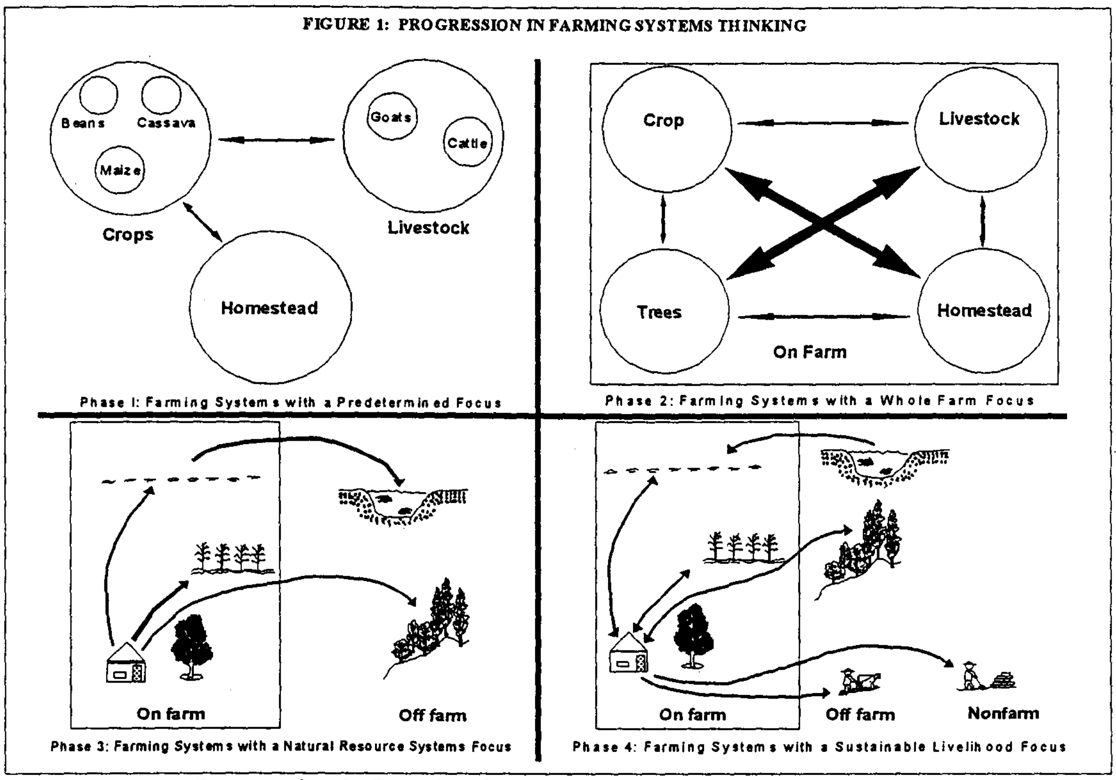


Figure 6-6. Progression in Farming Systems Thinking, according to D. W. Norman (2002)

According to Norman's model (Norman, 2002) for progression in Farming Thinking, expressed in figure 6-6, it can be said that Vaquerias farmers are in the middle of a transition between phase 1 and phase 2. In order to help to develop a decision making process that considers ecological-long run, off-farm and non-farm issues, a holistic focus could be the next step to walk, and the computer can be a useful tool for that. Computer use can be promoted to technicians; and computer's results can be promoted by teaching the advantage of the possibility to manage three aspects: holistic point of view, long-term consequences, and risk analysis.

In the Norman Farming System Model (1986), a physical-chemical factor line can be added to the "off farm" considerations that express the already existing ecological model and that can be adapted to be incorporated to a farm systems DSS. The issue is that all that technical element group, that presumes to know so well it has generated models for the simulation of information and crops, is not used by ignorance. The decision makers do not take advantage from them and each relatively successful cycle with its traditional system is another reason to strengthen the feedback chain to keep doing the same thing forever, regardless of technological, ecological or social changes. The decision makers do not take advantage for themselves, because not even their technical advisors know them.

An option for this new farmers (ex-ejidatarios), -with low resources, small extension agriculture-, could be having Universities and State Government promoting the creation of continuous learning and working groups, organized in a sustainable way more permanent that government periods. That organization should promote both, the on-farm work of technical advisors and not only inside the experimental stations), and the formation (training) of these technical advisors, in the principles, concepts and techniques of Farming System's Thinking (FST), Farming System Research and Extension (FSRE), ethnographic and social research, family agribusiness issues, and static and dynamic modeling and simulation.

Literally, J.B. Dent says:

> "Unfortunately though, the social aspects of agricultural systems have not received as much attention as the other areas. Consequently, existing models of farm household decision-making are neither powerfull nor transferable. This is unfortunate because models of whole farm

systems are becoming increasingly desirable for policy assessment and their utility in this context is currently limited by the relatively poor quality of socio-economic models. If whole farm models are to make a useful contribution to policy assessment, future research must concentrate on understanding the dynamics of the farm household, and in particular on how psychological and cultural variables impact on the decision-making process."(J. B. Dent, 1995)

"However, making the Farming System approach truly effective and widely adopted involves many challenges. The two major challenges are: the need for greater involvement and empowerment of farmers in the search for improvements; and the broader strategies needed to implement those improvements. The first implies a higher degree of locational and farmers' specificity, thereby possibly decreasing the potential multiplier effects of developmental efforts. The second implies the need for a new form of partnership between the different developmental stakeholders and institutions, and for greater liberalization of political structures and processes." (D. W. Norman, 2002)

It looks like failure in extension and technical advisory services is global. Walker (2002) says: "Failures can be attributed to non-delivery, non-adoption and to unexpected negative impacts where they are adopted." And he proposes to reconsider the support that is given to the decision-making. Loevinsohn (2002) proposes "A more informed use of learning approaches and decision support aids, supported by theory and evaluated experience" and in Australia they've created FARMSCAPE (Farmers', Advisers', Researchers', Monitoring, Simulation, Communication And Performance Evaluation) that is a program of participatory research with the farming community of northeast Australia. It initially involved research to explore whether farmers and their advisers could gain benefit from tools such as soil characterization and sampling, climate forecasts and, in particular, simulation modeling.

Conclusions

1. A model that represents the Vaquerias typical farming system is presented in chapter 3. By using sequential simulation, crop simulation models and a Ethnographic Linnear Programming model achieve realistically mimic the system. Yet it is neccesary some work in defining genetic coefficients for regional cultivars, and it is possible to specify household family issues.

2. Dry bean resulted to be a good potential alternative crop for the second crop cycle of the year, offering the highest annual family income.

3. Participatory methods on individual or very small groups showed to be more effective than large group activities. Training of technician and community leaders on computer skills could be the apropriate way to help´people taking advantage of computer model.

4. Farmers' decision making process is widely affected by the uncertainty environment and characterized by a risk management approach.

5. Active initiative of Universities is proposed to create a non-guvernmental learning community of technician and social leaders that help in research and extension of Farming System Thinking concepts.

Limitations

Some limitations of this study should be recognized. In spite of the fact that weather, crops, farming and communities are dynamic systems, this dissertation work captured the situation in a specific time, as in a photography. Therefor, it is logical to hope that there were changes of the future. Moreover, some of these changes are desirable and they should be motivated.

The lack of a local weather station forced us to work with approximations of calculated information. The lack of information about genetic coefficients forced us to work with generalizations.

Future Research

Future research following this same line coul include:

From technical subsystem: Weather local models, genetic coefficient calculation for local cultivars; object oriented simulation models for field, farm, off-farm, community and regional levels. Development of appropiate DSS that include production, economics, financial, quality and environmental sustainable citeria.Development of appropiate DSS' interfaces to allow farmers an easy access and use of DSS' tools. To incorporate family issues and personal priorities in a policy maker DSS' tool.

From human subsystem: To better understand how farmer's family issues influence on the decision making process. To develop strategies for helping the learning of Systems Thinking concepts, and Environmental Sustainability conscience, as well as community's integral development.

APPENDIX 1

Relationship between Sustainable Livelihood and

Farming Systems Research and Extension literature

Figure 3-2. Relationship between literature of Sustainable Livelihood (SL) and Farming Systems Research and Extension (FSRE).

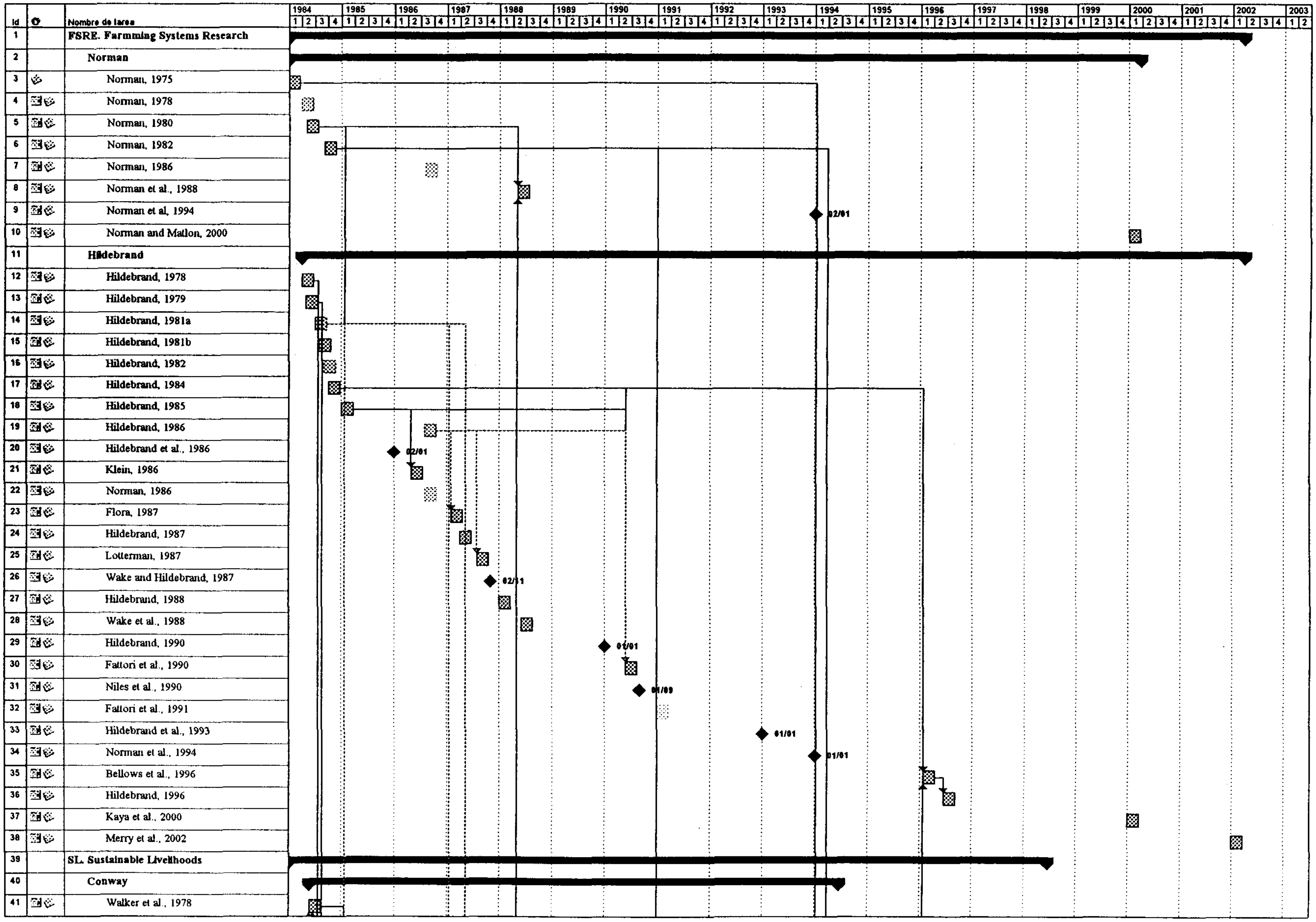
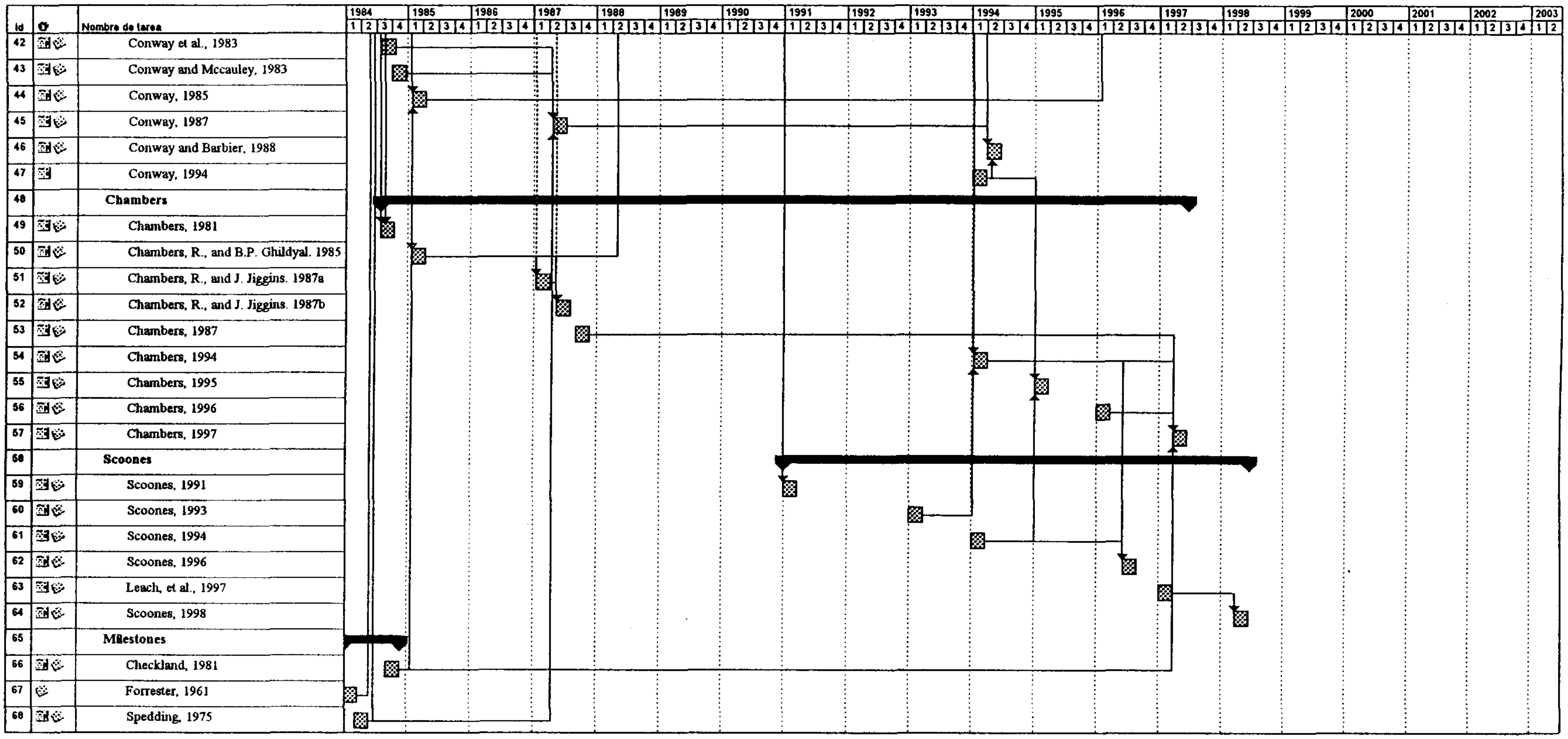


Figure 3-2. Relationship between literature of Sustainable Livelihood (SL) and Farming Systems Research and Extension (FSRE).



APPENDIX 2

Linear Programming model expressed in the LP General Format

GENERAL FORMAT OF THE LINEAR PROGRAMMING MODEL FOR EJIDO VAQUERIAS FARMING SYSTEM

First semester season

Objective function: Maximize Z = Final season cash

$Z = 1.2\ X_{107} + 200\ X_{108} + 1.5\ X_{109} + 8\ X_{110} + 20\ X_{116} + 300\ X_{120} + 1800\ X_{121} + 120\ X_{122} + 250\ X_{123} + X_{126} - X_{128}$

Subject to the next constrictions:

Capital

Initial cash: $-1550\ X_{101} -1550\ X_{102} -1950\ X_{103} -1850\ X_{104} -2150\ X_{105} -2050\ X_{106}\ -20\ X_{116} -150\ X_{117} -150\ X_{118}$ $-1000\ X_{119}\ \ -1\ X_{124}\ \ -1\ X_{126}\ 1\ X_{127}\ 1\ X_{128} = 0$ MxPesos

Procampo: $875\ X_{101} + 875\ X_{102} + 875\ X_{103} + 875\ X_{104} + 875\ X_{105} + 875\ X_{106}\ \ -1\ X_{127} = 0$ MxPesos

Household cash: $X_{124} = 2{,}500$ MxPesos

Land

Irrigated land $X_{101} + X_{103} + X_{105} \leq 11$ Hectares

Grassland: $X_{102} + X_{104} + X_{106} + 0.0003\ X_{117} + 0.0003\ X_{118} \leq 55$ Hectares

Labor

Own labor $6.5\ X_{101} + 6.5\ X_{102} + 8.5\ X_{103} + 8.5\ X_{104} + 10.5\ X_{105} + 10.5\ X_{106} + 1\ X_{122} + 1\ X_{123} \leq 150$ days

Hired labor $0\ X_{101} + 0\ X_{102} + 4\ X_{103} + 3\ X_{104} + 6\ X_{105} + 5\ X_{106} \Rightarrow 0$ days

Technical

Feasible cultivation $X_{102} + X_{104} \leq 1$ available dry land

Irrigation system $X_{103} \leq 1$ Hectares

Room limiting hen $X_{116} \leq 100$ units (heads)

Production

Sorghum grain $3000 X_{101} + 2000 X_{102} - 1 X_{107} = 0$ kilograms

Maize grain $2500 X_{103} + 1500 X_{104} - 1 X_{109} - 1 X_{112} - 7 X_{116} = 0$ kilograms

Beans grain $2000 X_{105} + 1000 X_{106} - 1 X_{111} - 1 X_{113} = 0$ kilograms

Sorghum forage rolls $6 X_{101} + 4 X_{102} - 1 X_{108} - 0.25 X_{117} - 0.25 X_{118} - 1.75 X_{119} = 0$ rolls

Maize straw bunches $300 X_{103} + 200 X_{104} - 1 X_{110} - 75 X_{117} - 75 X_{118} - 50 X_{119} = 0$ kilograms

Chicken $-1 X_{114} + 3 X_{116} \Rightarrow 0$ units (heads)

Eggs $-1 X_{115} + 90 X_{116} \Rightarrow 0$ units (eggs)

Sheep and goats $1 X_{117} + 1 X_{118} - 1 X_{120} = 0$ units (heads)

Calves $0.667 X_{119} - 1 X_{121} = 0$ units (heads)

Consumption:

Maize grain $X_{112} \Rightarrow 2500$ kilograms

Beans grain $X_{113} \Rightarrow 0$ kilograms

Chicken $X_{114} = 65$ number

Eggs $X_{115} = 1800$ number

Sorghum forage rolls consumption indicated in the production equation.

Maize straw bunches consumption indicated in the production equation.

Resulting Farm system

9.906 X_{101} **0.533** X_{102} **1.000** X_{103} **0.467** X_{104} **0.000** X_{105} **0.000** X_{106} **30,784.4** X_{107} **61.6** X_{108} **0.0** X_{109} **393** X_{110} **0.0** X_{111} **2,500** X_{112} **0.0** X_{113} **65** X_{114} **1,800** X_{115} **100** X_{116} **0** X_{117} **0** X_{118} **0** X_{119} **0** X_{120} **0** X_{121} **0** X_{122} **70** X_{123} **2500** X_{124} **0** **0** X_{126} **10,418** X_{127} **13,076** X_{128}

Z = 58,745 Mx$

Second semester season

Objective function: Maximize Z = Final annual cash

$Z = 0.8\,X_{207} + 100\,X_{208} + 1.5\,X_{209} + 8\,X_{210} + 3\,X_{211} + 20\,X_{216} + 300\,X_{220} + 1800\,X_{221} + 120\,X_{222} + 250\,X_{223} + X_{225} - X_{228}$

Subject to the next constrictions:

Capital

Initial cash $-1550\,X_{201} - 1550\,X_{202} - 1950\,X_{203} - 1850\,X_{204} - 2150\,X_{205} - 2050\,X_{206} - 20\,X_{216} - 150\,X_{217} - 150\,X_{218}$
$-1000\,X_{219} \quad -1\,X_{224} - 1\,X_{225}\ 1\,X_{226}\ 1\,X_{227}\ 1\,X_{228} = 0$ MxPesos

Procampo $875\,X_{201} + 875\,X_{202} + 875\,X_{203} + 875\,X_{204} + 875\,X_{205} + 875\,X_{206} \quad -1\,X_{227} = 0$ MxPesos

Transfered cash $X_{226} = 58{,}745$ MxPesos

Household cash $X_{224} = 3{,}000$ MxPesos

Land

Irrigated land $X_{201} + X_{203} + X_{205} <= 11$ Hectares

Grassland $X_{202} + X_{204} + X_{206} + 0.0003\,X_{217} + 0.0003\,X_{218} <= 55$ Hectares

Labor

Own labor $6.5\,X_{201} + 6.5\,X_{202} + 8.5\,X_{203} + 8.5\,X_{204} + 10.5\,X_{205} + 10.5\,X_{206} + X_{222} + X_{223} <= 150$ days

Hired labor $0\,X_{201} + 0\,X_{202} + 4\,X_{203} + 3\,X_{204} + 6\,X_{205} + 5\,X_{206} => 0$ days

Technical

Feasible cultivation $X_{202} + X_{204} <= 1$ irrigation times

Irrigation system $X_{203} <= 1$ Hectares

Room limiting hens $X_{216} <= 100$ units (heads)

Production

Sorghum grain $2000\,X_{201} + 1000\,X_{202} - 1\,X_{207} = 0$ kilograms

Maize grain $2500\,X_{203} + 1500\,X_{204} - 1\,X_{209} \quad -1\,X_{212} \quad -7\,X_{216} = 0$ kilograms

Beans grain $2000 X_{205} + 1000 X_{206} - 1 X_{211} - 1 X_{213} = 0$ kilograms
Sorghum forage rolls $4 X_{201} + 2 X_{202} - 1 X_{208} - 0.25 X_{217} - 0.25 X_{218} - 1.75 X_{219} = 0$ rolls
Maize straw bunches $300 X_{203} + 200 X_{204} - 1 X_{210} - 75 X_{217} - 75 X_{218} - 50 X_{219} = 0$ kilograms
Chicken $-1 X_{214} + 3 X_{216} => 0$
Eggs $-1 X_{215} + 90 X_{216} => 0$
Sheep and goats $1 X_{217} + 1 X_{218} - 1 X_{220} = 0$ units
Calves $0.667 X_{219} - 1 X_{221} = 0$ kilograms

<u>Consumption</u>

Maize grain $1 X_{212} => 2000$ kilograms
Beans grain $1 X_{213} => 3000$ kilograms
Chicken $1 X_{214} = 65$ number
Eggs $1 X_{215} = 1800$ number
Sorghum forage rolls consumption indicated in the production equation.
Maize straw bunches consumption indicated in the production equation.

Resulting Farm system

0.131 X_{201} **0.000** X_{202} **0.000** X_{203} **3.003** X_{204} **8.016** X_{205} **2.590** X_{206} **262.5** X_{207} **0.0** X_{208} **826.4** X_{209} **585.6** X_{210} **15,623** X_{211} **3,526** X_{212} **3,000** X_{213} **65** X_{214} **1800** X_{215} **22** X_{216} **0** X_{217} **0** X_{218} **0** X_{219} **0** X_{220} **0** X_{221} **0** X_{222} **12** X_{223} **3000** X_{224} **38731** X_{225} **58745** X_{226} **12023** X_{227} **0** X_{228}

Z (Capital Final annual cash) = 95,591 Mx$

APPENDIX 3

Farm Ethnographic Linear Programming model expressed in a spreadsheet

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
	in	Crop production enterprises for the 1st semester season											Consumption				An[illegible]						[illegible]		[illegible]							
Available Livelihoods the 1st semester season		They plant hectares of						to sell kilograms of					and to consume by				They produce amounts of				[illegible]		They need days		Money needed							
		Sorghum		Maize		Beans		Sorghum		Maize		Beans	Family				Hens	Sheep	Goats	Cattle	Sheep	Cattle	for paid job		for house	for save	for transfer	from PROCAMPO	from credit			
		Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	grain	forage rolls	grain	staws	grain	maize	beans	Chicken	Eggs							on other's farms	at the city				1st				
	Farm system	[illegible]	0.533	1.000	0.467	0.000	0.000	30,784.4	61.6	0.0	393	0.0	2,500	0.0	65	1,800	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	USE	=	RHS
	Initial cash	-1550	-1550	-1950	-1850	-2150	-2050										-20	-150	-150	-1000					-1		-1	1	1	0	=	0
Capital*	Procampo	875	875	875	875	875	875																					-1		0	=	0
	Household cash																								1					2,500	=	2,500
Land	Irrigated land	1		1		1																								11	<=	11
	Grassland		1		1		1											0.0003	0.0003											1	<=	55
Labor	Own labor	6.5	6.5	8.5	8.5	10.5	10.5																1	1						150	<=	150
	Hired labor	0	0	4	3	6	5																							5	=>	0
	Feasible cultivation		1		1																									1	<=	1
Tech	Irrigation system			1																										1	<=	1
	Room limited																1													100	<=	100
	Sorghum grain	3000	2000					-1																						0	=	0
	Maize grain			2500	1500					-1			-1				-7													0	=	0
	Beans grain					2200	1100					-1		-1																0	=	0
	Sorghum forage rolls	6	4						-1									-0.25	-0.25	-1.75										0	=	0
Production	Maize straw bunches			300	200						-1							-75	-75	-50										0	=	0
	Chicken														-1		3													235	=>	0
	Eggs															-1	90													7,200	=>	0
	Sheep and goats																	1	1		-1									0	=	0
	Calves																			0.667		-1								0	=	0
	Maize grain												1																	2,500	=>	2500
	Beans grain													1																0	=>	0
Consumption	Sorghum forage rolls																													0	=	0
	Maize straw bunches																													0	=	0
	Chicken														1															65	=	65
	Eggs															1														1,800	=	1800
Capital	Final season cash	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	=>	0

	in	Crop production enterprises for the 2st semester season											Consumption				An[illegible]						[illegible]		[illegible]							
Available Livelihoods the 2st semester season		They plant hectares of						to sell kilograms of					and to consume by				They produce amounts of				[illegible]		They need days		Money needed							
		Sorghum		Maize		Beans		Sorghum		Maize		Beans	Family				Hens	Sheep	Goats	Cattle	Sheep	Cattle	for paid job		for house	for save	from transfer	from PROCAMPO	from credit			
		Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	grain	forage rolls	grain	staws	grain	maize	beans	Chicken	Eggs							on other's farms	at the city				2nd				
	Farm system	0.131	0.000	[illegible]	3.003	[illegible]	[illegible]	[illegible]	0.0	826.4	[illegible]	#####	3,526	3,000	65	1800	22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		USE	=	RHS
	Initial cash	-1550	-1550	-1950	-1850	-2150	-2050										-20	-150	-150	-1000					-1	-1	1	1	1	0	=	0
Capital*	Procampo	875	875	875	875	875	875																					-1		0	=	0
	Transfered cash																										1			58,745	=	[illegible]
	Household cash																								1					3,000	=	3,000
Land	Irrigated land	1		1		1																								8	<=	11
	Grassland		1		1		1											0.0003	0.0003											6	<=	55
Labor	Own labor	6.5	6.5	8.5	8.5	10.5	10.5																1	1						150	<=	150
	Hired labor	0	0	4	3	6	5																							70	=>	0
	Feasible cultivation		1		1																									0	<=	1
Tech	Irrigation system			1																										0	<=	1
	Room limited																1													3	<=	100
	Sorghum grain	2000	1000					-1																						0	=	0
	Maize grain			2500	1500					-1			-1				-7													0	=	0
	Beans grain					2000	1000					-1		-1																0	=	0
	Sorghum forage rolls	4	2						-1									-0.25	-0.25	-1.75										0	=	0
Production	Maize straw bunches			300	200						-1							-75	-75	-50										0	=	0
	Chicken														-1		3													0	=>	0
	Eggs															-1	90													150	=>	0
	Sheep and goats																	1	1		-1									0	=	0
	Calves																			0.667		-1								0	=	0
	Maize grain												1																	3,526	=>	2000
	Beans grain													1																3,000	=>	3000
Consumption	Sorghum forage rolls																													0	=	0
	Maize straw bunches																													0	=	0
	Chicken														1															65	=	65
	Eggs															1														1,800	=	1800
Capital	Final annual cash	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	=>	0

APPENDIX 4

Soil Data Files and example of a Weather Data File

```
*SOILS

*TMVA940001  SCS         SICL      162 Vaquerias, tierra blanca (white soil)
@SITE        COUNTRY          LAT     LONG SCS FAMILY
 VAQUERIAS   MEXICO       25.071  -99.010 ARIDISOL, Ustollic Calciorthids
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
 G      0.13  10.5  0.40    76  1.00  1.00 IB001 IB001 IB001
@  SLB SLMH   SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC
    18 AK    0.161 0.291 0.410  0.15 -99.0  1.33 41.30  31.0  52.0   5.0   -99   8.1 -99.0 -99.0
    49 AK    0.157 0.282 0.402  0.75 -99.0  1.33 42.40  31.5  48.0   8.0   -99   8.1 -99.0 -99.0
    93 AC    0.149 0.280 0.406  0.50 -99.0  1.35 45.00  28.0  51.5   4.0   -99   8.0 -99.0 -99.0
   134 CK    0.120 0.249 0.384  0.00 -99.0  1.38 49.10  21.0  44.0   2.0   -99   7.5 -99.0 -99.0
   162 CK    0.128 0.257 0.382  0.00 -99.0  1.40 48.20  23.0  42.0   2.0   -99   7.6 -99.0 -99.0

*TMVA940002  SCS         SICL     135 VAQUERIAS, TIERRA NEGRA (BLACK SOIL)
@SITE        COUNTRY          LAT     LONG SCS FAMILY
 VAQUERIAS   MEXICO       25.065  -99.000 ARIDISOL VERTIC HAPLARGIDS
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
 BK     0.09  11.8  0.20    76  1.00  1.00 IB001 IB001 IB001
@  SLB SLMH   SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC
    20 AP    0.240 0.372 0.387  1.00 -99.0  1.58 20.40  48.0  51.0   5.0  0.10   8.3 -99.0  24.6
    42 AK    0.267 0.395 0.410  0.50 -99.0  1.73 24.80  53.5  38.5   3.0  0.16   8.3 -99.0  29.3
    72 AK    0.272 0.403 0.418  0.50 -99.0  1.75 21.60  53.5  43.0   0.0  0.12   8.3 -99.0  26.7
   101 AK    0.270 0.403 0.418  0.50 -99.0  1.78 34.00  53.5  43.0   0.0  0.10   8.4 -99.0  23.2
   122 BW    0.240 0.362 0.377  0.50 -99.0  1.65 28.00  46.5  23.5   0.0  0.07   8.4 -99.0  23.1
   135 BW    0.248 0.382 0.397  0.50 -99.0  1.55 18.00  48.0  48.5   0.0  0.07   8.1 -99.0  23.1

*TMVA910001  SCS         SICL     100 VAQUERIAS, TIERRA BLANCA (WHITE SOILS)
@SITE        COUNTRY          LAT     LONG SCS FAMILY
 VAQUERIAS   MEXICO       25.072  -99.014 ARIDISOL USTOLLIC CALCIORTHIDS
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
 G      0.13  11.0  0.40    76  1.00  1.00 IB001 IB001 IB001
@  SLB SLMH   SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC
    30       0.200 0.328 0.390  0.20 -99.0  1.50  1.93  37.5  41.0   2.0  0.25   7.9 -99.0  22.5
    70       0.177 0.305 0.386  0.20 -99.0  1.53  1.09  32.0  41.0   1.0  0.17   7.9 -99.0  15.8
   100       0.207 0.334 0.386  0.00 -99.0  1.65  0.68  38.5  38.5   0.0  0.14   8.0 -99.0  12.3
```

```
*TMVA910002  SCS          SICL    150 VAQUERIAS, TIERRA NEGRA (BLACK SOILS)
@SITE        COUNTRY           LAT     LONG SCS FAMILY
 VAQUERIAS   MEXICO        25.060  -99.004 ARIDISOL USTOLLIC CALCIORTHIDS
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
 BK     0.09  10.5  0.40    76  1.00  1.00 IB001 IB001 IB001
@  SLB SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC
    15      0.172 0.304 0.410  1.00 -99.0  1.63  1.66  31.0  50.5   2.0  0.23   8.2 -99.0  22.2
    30      0.204 0.337 0.398  1.00 -99.0  1.58  1.53  38.0  52.0   1.0  0.20   8.1 -99.0  21.6
    70      0.209 0.340 0.406  0.15 -99.0  1.47  0.57  39.0  45.0   0.0  0.12   8.1 -99.0  21.4
   120      0.160 0.293 0.400  0.00 -99.0  1.56  0.29  28.0  50.0   0.0  0.09   8.0 -99.0  28.4
   150      0.160 0.293 0.400  0.00 -99.0  1.57  0.25  28.0  50.0   0.0  0.08   7.8 -99.0  18.7

*TMVA030001  SCS          SICL    100 VAQUERIAS, TIERRA BLANCA (WHITE SOILS)
@SITE        COUNTRY           LAT     LONG SCS FAMILY
 VAQUERIAS   MEXICO        25.072  -99.014 ARIDISOL USTOLLIC CALCIORTHIDS
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
 G      0.13  11.1  0.40    76  1.00  1.00 IB001 IB001 IB001
@  SLB SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC
    30      0.204 0.327 0.377  0.20 -99.0  1.50  2.10  38.3  33.3   2.0  0.10   8.3 -99.0  22.5
    70      0.187 0.313 0.381  0.20 -99.0  1.53  0.84  34.3  37.3   1.0  0.04   8.3 -99.0  15.8
   100      0.188 0.313 0.374  0.00 -99.0  1.65  0.69  34.3  33.6   0.0  0.03   8.4 -99.0  12.3

*TMVA030002  SCS          SICL    150 VAQUERIAS, TIERRA NEGRA (BLACK SOIL)
@SITE        COUNTRY           LAT     LONG SCS FAMILY
 VAQUERIAS   MEXICO        25.060  -99.004 ARIDISOL VERTIC HAPLARGIDS
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
 BK     0.09  11.4  0.40    76  1.00  1.00 IB001 IB001 IB001
@  SLB SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC
    15      0.221 0.345 0.382  1.00 -99.0  1.65  2.70  42.3  34.9   2.0  0.13   8.1 -99.0  22.2
    30      0.214 0.337 0.375  1.00 -99.0  1.60  2.77  40.3  31.6   1.0  0.14   8.1 -99.0  21.6
    70      0.209 0.339 0.409  0.15 -99.0  1.50  0.60  39.0  43.0   0.0  0.12   8.1 -99.0  21.4
   120      0.160 0.291 0.390  0.00 -99.0  1.50  0.30  28.0  45.0   0.0  0.09   8.0 -99.0  28.4
   150      0.160 0.293 0.400  0.00 -99.0  1.60  0.30  28.0  50.0   0.0  0.08   7.8 -99.0  18.7
```

*WEATHER DATA : VAQUERIAS,MEXICO Datos generados por SIMETEO

@ INSI	LAT	LONG	ELEV	TAV	AMP	REFHT	WNDHT
TMVA	25.066	-99.010	150	18.0	13.0	3.0	3.0

@DATE	SRAD	TMAX	TMIN	RAIN
03001	9.2	23.0	5.2	0.0
03002	5.0	20.0	9.0	5.2
03003	3.7	18.9	11.8	26.5
03004	3.7	16.0	10.8	0.2
03005	18.2	18.2	6.2	0.0
03006	11.8	19.6	3.6	0.0
03007	18.0	20.8	6.7	0.0
03008	13.7	19.1	3.8	0.0
03009	15.6	18.1	2.0	0.0
03010	12.0	18.5	4.4	0.0
03011	15.5	16.3	4.8	0.0
03012	12.0	14.4	4.4	0.0
03013	12.3	12.7	2.3	0.0
03014	17.7	17.3	-0.2	0.0
03015	16.2	17.9	0.6	0.0
03016	10.1	19.1	5.7	0.0
03017	6.5	18.9	8.6	0.0
03018	7.7	20.1	12.5	0.0
03019	13.2	16.6	6.0	0.0
03020	7.7	17.3	4.2	0.0
03021	3.9	16.1	2.8	0.0
03022	10.4	22.7	7.6	0.0
03023	4.7	18.8	10.6	0.0
03024	11.4	21.9	8.8	0.0
03025	15.3	23.8	9.5	0.0
03026	11.8	23.9	11.5	0.0
03027	16.3	25.4	10.5	0.0
03028	20.4	20.7	9.0	0.0
03029	13.9	16.5	5.5	0.0
03030	17.9	18.5	-0.0	0.0
03031	14.1	18.6	4.3	0.0
03032	17.3	20.6	4.1	0.0
03033	19.0	23.0	4.9	0.0
03034	21.1	24.9	6.0	0.0
03035	11.9	19.5	1.9	0.0
03036	12.7	19.0	5.7	0.0
03037	11.6	17.8	9.3	0.0
03038	18.3	17.6	9.2	0.0
03039	12.3	20.2	9.7	0.0
03040	17.8	25.8	13.8	0.0
03041	19.7	31.9	16.0	0.0
03042	9.5	25.2	7.1	0.0
03043	10.9	30.5	17.2	0.0
03044	15.8	28.9	12.3	0.0
03045	18.1	26.5	7.4	0.0
03046	16.4	21.1	3.7	0.0
03047	15.3	18.1	3.6	0.0
03048	17.2	22.5	8.4	0.0
03049	20.3	23.5	8.1	0.0
03050	22.7	23.7	7.0	0.0
03051	23.3	25.7	7.9	0.0

03052	23.4	27.6	8.3	0.0
03053	9.2	23.0	9.4	0.0
03054	15.5	23.9	9.8	0.0
03055	20.6	23.3	5.2	0.0
03056	16.6	21.5	1.3	0.0
03057	22.7	20.8	4.8	0.0
03058	22.1	22.8	6.8	0.0
03059	16.2	27.7	14.4	0.0
03060	24.2	28.0	13.1	0.0
03061	4.9	18.2	9.5	9.7
03062	22.4	27.8	14.4	0.0
03063	21.6	27.8	14.7	0.0
03064	15.7	28.4	14.7	0.0
03065	18.0	29.4	16.8	0.0
03066	17.0	27.1	17.5	0.0
03067	13.9	27.3	15.4	0.0
03068	18.2	27.5	18.7	0.0
03069	18.4	27.9	18.5	0.0
03070	17.7	28.5	16.2	0.0
03071	22.1	27.2	15.7	0.0
03072	26.2	33.0	15.7	0.0
03073	16.7	29.5	17.5	0.0
03074	24.1	25.4	13.9	0.0
03075	18.7	27.6	11.0	0.0
03076	18.7	25.7	8.6	0.0
03077	26.7	27.6	6.5	0.0
03078	18.3	23.7	8.5	0.0
03079	22.7	27.4	8.1	0.0
03080	22.4	30.3	8.4	0.0
03081	20.5	34.5	12.4	0.0
03082	18.8	33.4	14.0	0.0
03083	16.7	32.3	15.4	0.0
03084	19.7	28.9	15.7	0.0
03085	13.3	25.7	14.0	0.0
03086	18.4	21.2	11.9	0.0
03087	21.2	25.6	12.7	0.0
03088	26.4	28.7	11.7	0.0
03089	19.1	30.1	13.9	0.0
03090	16.8	27.4	16.1	0.0
03091	8.4	19.3	16.7	1.4
03092	12.8	18.6	14.5	9.7
03093	22.6	29.3	14.0	0.0
03094	18.7	27.0	13.5	0.0
03095	27.6	27.7	12.7	0.0
03096	19.0	26.5	14.7	0.0
03097	20.4	26.0	12.4	0.0
03098	18.2	24.2	16.4	12.8
03099	18.7	28.1	15.1	0.0
03100	19.9	27.9	14.3	0.0
03101	20.0	29.8	15.8	0.0
03102	17.9	28.0	15.8	0.0
03103	28.8	31.5	18.1	0.0
03104	24.9	34.3	19.7	0.0
03105	27.8	33.2	16.0	0.0
03106	21.5	32.7	18.4	0.0
03107	21.9	34.6	17.8	0.0

APPENDIX 5

Original Farm LP Model

Available Livelihoods in the 1st semester season		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
		Crop production enterprises for the 1st semester season											Consumption				[illegible]						[illegible]		[illegible]							
		They plant hectares of						to sell kilograms of					and to consume by				They produce amounts of				[illegible]		They need days		Money needed							
		Sorghum		Maize		Beans		Sorghum		Maize		Beans	Family				Hens	Sheep	Goats	Cattle	Sheep	Cattle	for paid job		for house	for save	for transfer	from PROCAMPO	from credit			
		Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	grain	forage rolls	grain	staws	grain	maize	beans	Chicken	Eggs							on other's farms	at the city				1st				
	Farm system	1.906	0.533	1.000	0.467	0.000	0.000	30,784.4	61.6	0.0	393	0.0	2,500	0.0	65	1,800	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	USE	=	RHS
Capital*	Initial cash	-1550	-1550	-1950	-1850	-2150	-2050										-20	-150	-150	-1000					-1		-1	1	1	0	=	0
	Procampo	875	875	875	875	875	875																					-1		0	=	0
	Household cash																								1					2,500	=	2,500
Land	Irrigated land	1		1		1																								11	<=	11
	Grassland		1		1		1											0.0003	0.0003											1	<=	55
Labor	Own labor	6.5	6.5	8.5	8.5	10.5	10.5																1	1						150	<=	150
	Hired labor	0	0	4	3	6	5																							5	=>	0
Tech	Feasible cultivation		1		1																									1	<=	1
	Irrigation system			1																										1	<=	1
	Room limited																1													100	<=	100
Production	Sorghum grain	3000	2000					-1																						0	=	0
	Maize grain			2500	1500					-1			-1				-7													0	=	0
	Beans grain					2200	1100					-1		-1																0	=	0
	Sorghum forage rolls	6	4						-1									-0.25	-0.25	-1.75										0	=	0
	Maize straw bunches			300	200						-1							-75	-75	-50										0	=	0
	Chicken														-1		3													235	=>	0
	Eggs															-1	90													7,200	=>	0
	Sheep and goats																	1	1		-1									0	=	0
	Calves																			0.667		-1								0	=	0
Consumption	Maize grain												1																	2,500	=>	2500
	Beans grain													1																0	=>	0
	Sorghum forage rolls																													0	=	0
	Maize straw bunches																													0	=	0
	Chicken														1															65	=	65
	Eggs															1														1,800	=	1800
Capital	Final season cash	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	=>	0

Available Livelihoods in the 2st semester season		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
		Crop production enterprises for the 2st semester season											Consumption				[illegible]						[illegible]		[illegible]							
		They plant hectares of						to sell kilograms of					and to consume by				They produce amounts of				[illegible]		They need days		Money needed							
		Sorghum		Maize		Beans		Sorghum		Maize		Beans	Family				Hens	Sheep	Goats	Cattle	Sheep	Cattle	for paid job		for house	for save	from transfer	from PROCAMPO	from credit			
		Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	grain	forage rolls	grain	staws	grain	maize	beans	Chicken	Eggs							on other's farms	at the city				2nd				
	Farm system	[illegible]	0.000	0.800	[illegible]	[illegible]	[illegible]	[illegible]	0.0	826.4	[illegible]	[illegible]	3,526	3,000	65	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		USE	=	RHS
Capital*	Initial cash	-1550	-1550	-1950	-1850	-2150	-2050										-20	-150	-150	-1000					-1	-1	1	1	1	0	=	0
	Procampo	875	875	875	875	875	875																					-1		0	=	0
	Transfered cash																										1			58,745	=	[illegible]
	Household cash																								1					3,000	=	3,000
Land	Irrigated land	1		1		1																								8	<=	11
	Grassland		1		1		1											0.0003	0.0003											6	<=	55
Labor	Own labor	6.5	6.5	8.5	8.5	10.5	10.5																1	1						150	<=	150
	Hired labor	0	0	4	3	6	5																							70	=>	0
Tech	Feasible cultivation		1		1																									0	<=	1
	Irrigation system			1																										0	<=	1
	Room limited																1													3	<=	100
Production	Sorghum grain	2000	1000					-1																						0	=	0
	Maize grain			2500	1500					-1			-1				-7													0	=	0
	Beans grain					2000	1000					-1		-1																0	=	0
	Sorghum forage rolls	4	2						-1									-0.25	-0.25	-1.75										0	=	0
	Maize straw bunches			300	200						-1							-75	-75	-50										0	=	0
	Chicken														-1		3													0	=>	0
	Eggs															-1	90													150	=>	0
	Sheep and goats																	1	1		-1									0	=	0
	Calves																			0.667		-1								0	=	0
Consumption	Maize grain												1																	3,526	=>	2000
	Beans grain													1																3,000	=>	3000
	Sorghum forage rolls																													0	=	0
	Maize straw bunches																													0	=	0
	Chicken														1															65	=	65
	Eggs															1														1,800	=	1800
Capital	Final annual cash	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	=>	0

APPENDIX 6

Production and Sales activities in the Farm Model.

		[redacted]														9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
		Crop production enterprises for the 1st semester season																	Consumption				Animal production enterprises						Other activities		[redacted]							
Available Livelihoods in the 1st semester season		They plant hectares of									to sell kilograms of								and to consume by				by produce amount				l amoun		They need days		Money needed							
		Sorghum		[redacted]			Maize		Beans		Sorghum		[redacted]			Maize		Bea	Family				Hen	Shee	Goat	Catt	Hen	Catt	for paid job		for ho	for sa	for tran	PROCAM	from credit			
		Irriga	Non-irrigated				Irriga	Non-irrig	Irriga	Non-irrig	grain	forage rolls				grain	straw	grain	maize	beans	chicken	Eggs							on other's	at the city				1st				
	Farm system	###	0.533				###	0.467	####	0.000	####	61.6				0.0	##	0.0	##	0.0	[illegible]	##	#	0	0	0	0	0	0	70	2500	0	0	10,418	####	USE	=	RHS
	Initial cash	####	-1550				####	-1850	####	-2050													-20	###	###	###					-1		-1	1	1	0	=	0
Capital*	Procampo	875	875				875	875	875	875																								-1		0	=	0
	Household cash																														1					###	=	###
Land	Irrigated land	1					1		1																											11	<=	11
	Grassland		1					1		1														###	###											1	<=	55
Labor	Own labor	6.5	6.5				8.5	8.5	10.5	10.5																			1	1						150	<=	150
	Hired labor	0	0				4	3	6	5																										5	>=	0
	Feasible cultivation		1					1																												1	<=	1
Tech	Irrigation system						1																													1	<=	1
	Room limited																						1													100	<=	100
	[redacted]	3000	2000								-1																									0	=	0
				5500									-1																									
					3500									-1																								
						1200									-1																							
	Beans grain								2200	1100								-1		-1																0	=	0
Productio	Maize grain						2500	1500								-1			-1				-7													0	=	0
	Sorghum fora	6	4									-1												-0	-0	-2										0	=	0
	Maize straw bunches						300	200									-1							-75	-75	-50										0	=	0
	Chicken																				-1		3													235	>=	0
	Eggs																					-1	90													###	>=	0
	Sheep and goats																							1	1		-1									0	=	0
	Calves																									###		-1								0	=	0
	Maize grain																		1																	###	>=	###
	Beans grain																			1																0	>=	0
onsumpti	Sorghum forage rolls																																			0	=	0
	Maize straw bunches																																			0	=	0
	Chicken																				1															65	=	65
	Eggs																					1														###	=	###
Capital	Final season cash										12	200															300	##	120	250			1	0		###	>=	0

		[redacted]																																				
		Crop production enterprises for the 2st semester season																	Consumption				Animal production enterprises						Other activities		[redacted]							
Available Livelihoods in the 2st semester season		They plant hectares of									to sell kilograms of								and to consume by				by produce amount				l amoun		They need days		Money needed							
		Sorghum		[redacted]			Maize		Beans		Sorghum		[redacted]			Maize		Bea	Family				Hen	Shee	Goat	Catt	Hen	Catt	for paid job		for ho	for sa	from tran	PROCAM	from credit			
		rigate	on-irrigated				Irrigate	on-irrigat	rigate	on-irrigat	grain	rage rolls				grain	straw	grain	maize	bean	chick	Eggs							on other's farm	the city				2nd				
	Farm system	####	0.000				####	3.003	####	2.590	262.5	0.0				####	###	##	##	##	65	###	32	0	0	0	0	0	0	12	3080	[illegible]	[illegible]	[illegible]		USE	=	RHS
	Initial cash	####	-1550				####	-1850	####	-2050													-20	###	###	###					-1	-1	1	1	1	0	=	0
Capital*	Procampo	875	875				875	875	875	875																								-1		0	=	0
	Transfered cash																																1			###	=	[illegible]
	Household cash																														1					###	=	###
Land	Irrigated land	1					1		1																											8	<=	11
	Grassland		1					1		1														###	###											6	<=	55
Labor	Own labor	6.5	6.5				8.5	8.5	10.5	10.5																			1	1						150	<=	150
	Hired labor	0	0				4	3	6	5																										70	>=	0
	Feasible cultivation		1					1																												0	<=	1
Tech	Irrigation system						1																													0	<=	1
	Room limited																						1													3	<=	100
	[redacted]	2000	1000								-1																									0	=	0
						1200									-1																							
									2000	1000								-1		-1																0	=	0
	Maize grain						2500	1500								-1			-1				-7													0	=	0
Productio	Sorghum fora	4	2									-1												-0	-0	-2										0	=	0
	Maize straw bunches						300	200									-1							-75	-75	-50										0	=	0
	Chicken																				-1		3													0	>=	0
	Eggs																					-1	90													150	>=	0
	Sheep and goats																							1	1		-1									0	=	0
	Calves																									###		-1								0	=	0
	Maize grain																		1																	###	>=	###
	Beans grain																			1																###	>=	###
onsumpti	Sorghum forage rolls																																			0	=	0
	Maize straw bunches																																			0	=	0
	Chicken																				1															65	=	65
	Eggs																					1														###	=	###
Capital	Final annual cash								[illegible]	[illegible]	12	100	4.5										20				300	##	120	250		1		0	-1	###	>=	0

APPENDIX 7

Guide for conversations

Information of Vaquerías' farmers in Gral. Terán, N. L., México.

Guide to personal conversations.

1. ¿Which crop do you plant in the first cycle: __________; in the second __________?
2. What would you farm other than sorghum? ______________________________
3. Why sorghum was chosen as a crop: ______________________________
   a) Quantity enough to feed family
   b) Quantity enough to feed family and animals and sell to market
   c) More money Higher profit
   d) Money loan has a locked destiny crop
   e) Client / Market ask for it
   f) Family nutrition or likes
   g) Best for ecosystem
   h) Easier to find inputs for it
   i) Easier to find labor for it
   j) Requires less/cheaper labor
   k) Easier to sell
   l) Less competence
   m) Most people plant it in the community
   n) Governmental program
   o) People (consumers) look for a modern / organic crop
   p) Technology (as irrigation) allow us
   q) the crop we best know
   r) It has good yield in here
   s) Because it give us two crops wit one planting
   t) It requier not so much work
   u) because it is safer
4. Do you chose te plant other crop if:
   a. Finance loan is chained to a specific crop?
   b. Other farmers plant it?
   c. Your technician – advisor recommend it?
   d. If a guvernmental program promote it?
5. Do you know computers?
6. Do you know computers can make calculus about your possible profit?
7. Why do not use them?
8. There is a computer in the community elementary school and another in the technician house:
9. Requisite for believing in the computer program
   a. It proves it works.
   b. Understanding how the computer model works
   c. Technician recommendation.
   d. Computer agrees with me.

ONCE MODEL IS DEMOSTRATED...

- Now you know computer model's results agree with your thinking, would you decide based on computer model?
- Now you know computer model's results agree with your technician's thinking, would you decide based on computer model?
- Now you know computer model's results agree with your partners' thinking, would you decide based on computer model?

ONCE RESULTS IS SHOWED

10. Computer model's results recomend to plant dry beans: What do you think? What's your opinion?
    a. We have to do it!
    b. It can works, since we already plant dry bean in a non-commercial way.
    c. Maybe it is OK; maybe it is not. Probably I will wait to see other farmers to success with that before I plant a different crop.
    d. I do not think we should leave from a secure well-known crop.
    e. Definitively no. Because:
        i. It require so much work (related to labor).
        ii. Dry bean is a delicated crop (Attitud – work)
        iii. Who is going to buy it? (Market)

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