AN EVALUATION OF THE MEXICAN BEEF

CATTLE INDUSTRY

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INTRODUCTION

With the implementation of free trade among the North American countries, many aspects of production agriculture have the potential to change dramatically. Beef production as an industry has existed at different levels of intensity in the United States, Canada and Mexico for an extended period of time. The United States is well known for its high quality standards and its remarkable forward movement in the beef industry. Canada has followed that example and developed a beef industry comparable to that of the United States in quality but only a fraction of its size. However, the Mexican beef industry has struggled to advance their technology and improve the production of beef products.

Given the implementation of free trade, the cattle industry in Mexico has the unique possibility to grow and expand rapidly throughout the next decade. Mexico has a widespread cattle industry due to its vast amount of land suitable for livestock production. Mexico currently struggles with their ability to efficiently produce beef Many factors have slowed the progress of the Mexican beef industry including, agricultural policy, drought conditions, disease and pest problems, high grain prices, and an unstable economy. In 1999, government policy is more favorable toward the cattle producer and the economy in Mexico is fairly stable. It is also evident that producers, breed associations, and government programs are working toward improving production efficiency. They have begun to implement strategies that will overcome the challenges that Mexican producers face. So the question remains what progress is possible for the Mexican cattle industry? Given Mexico's unique resource base how will the adaptation of new technology or increased demand alter their productive efficiency and their overall herd size. By determining Mexican cattle industry's reaction to North American Free Trade Agreement (NAFTA), it is possible to determine the effect of NAFTA on the U.S. cattle industry and its producers.

A unique market has developed for United States beef producers in the last ten years. The growing demand for beef in Mexico has prompted the importation of an increasing quantity of red meat from the United States. Mexico has become the second largest importer of U.S. beef products. Since the late 1980s, red meat exports to Mexico have increased from 22,000 metric tons in 1987 to 154,582 metric tons in 1998 (Peel; USDA, 1999a). Mexico's continuous struggle to remain productively efficient is evident when compared to United States production Mexico produced approximately 1.8 million metric tons of beef in 1997 with a total herd of 26.9 million head (USDA, 1999a. While in comparison the United States produced over 11.7 million metric tons of beef with a total herd of 101 million head in 1997 (Food and Agricultural Organization of the United Nations).

General Objective

The general objective of this research is to construct a model of the Mexican cattle industry that has the capabilities to consider the resource limitations, the productivity of the herd, and the changing demand of the Mexican consumers.

Specific Objective

The specific objective of this study is to determine the quantity and quality of beef cattle produced in Mexico, given their range and pasture resources, if trade flows freely between the United States and Mexico. More specifically this research analyzes the change in the quantity of beef cattle produced if beef demand in Mexico changes in terms of quality or quantity and if the productivity of the Mexican cow herd improves.

Mexican Cattle Production Regions

Mexico uses 63 percent of its land area for the production of livestock (Cockerham). The majority of that land is used for beef, dairy, or dual-purpose cattle production. Cockerham and SAGAR agree that as with U.S. production, Mexico's production is divided into three geo-climatic regions: arid/semiarid, temperate, and tropical. These regions all possess unique characteristics that make cattle production in that region special to that specific area.

Arid or Semiarid Region

The arid/semiarid region encompasses most of the northern region of Mexico. Beef production is found in over 70 percent of this region. This includes the states of Baja California Sur, Baja California, Chihuahua, Coahuila, Durango, Nuevo Leon, San Luis Potosi, Sonora, Tamaulipas, and Zacatecas (Figure 1.1) (SAGAR). The arid/semiarid region is characterized by its extreme conditions such as low rainfall amounts, poor distribution of precipitation, occasional torrential rains or droughts, and extreme temperature variations (Villalobos). The average rainfall in this region ranges from 7.9 to 31.5 inches annually although rainfall in Sonora can be as low as two inches per year (Cockerham). The rainy season is in the summer and early fall and the temperature ranges from cool to cold in the winter to very hot in the summer. One of the major problems in this region is lack of rainfall (Cockerham). This region has faced severe droughts in the past years causing many producers to slaughter large percentages of their herd (SAGAR).

The vegetation that has developed is mainly desert scrub or semi-arid grassland. Some of the species in this area are desirable forage plants for livestock and wildlife but many are of little forage value. Due to the ecological conditions of this area and the destructive overgrazing, large areas of bare ground exist. Very little has been done to improve or revegetate these areas. Therefore, the region consists of mostly natural rangelands, and supplemental feeding practices are common in the winter and spring (Villalobos). Stocking rates vary in this region from 6 to 15 hectares per animal unit (15 to 37 acres) (Organizacion De Las Naciones Unidas Para La Agricultura Y La Alimentacion.). Bredahl, Burst, and Warnken state that the ranges of the northern cattle regions are under such heavy grazing that productivity is being reduced and water resources are being depleted. This region faces great challenges due to their inability to overcome their environmental limitations

This region accounts for approximately 26 percent of Mexico's cattle herd, with 7.7 million cattle here in 1997. The important cattle-producing states in this area include Chihuahua, Durango, and Sonora. Durango has the highest population of cattle in this region with 1.165 million head in 1997. The leading state for cattle production in this region changed dramatically from 1992 to 1999. Due to severe drought conditions nearly fifty percent of the herds in Chihuahua and Coahuila were slaughtered between 1994 and

1996 (SAGAR). Due to the close proximity to the U.S., the primary cattle production here is feeder cattle. The majority of steers raised here are exported to the U.S. as feeder calves. Since the market for these cattle is the United States, improved cattle are prevalent in this region this includes many European or predominantly European breeds, such as Charolais, Hereford, Angus, Beefmaster and Santa Gertrudis (Cockerham).

Temperate Region

The temperate region is located in the central part of Mexico and consists of the states of Aguascalientes, Guanajuato, Hidalgo, Jalisco, Mexico, Michoacan, Oaxaca, Puebla, Queretaro, and Tlaxcala plus the Federal District (Figure 1.1) (SAGAR). High mountains and flat valleys characterize this region Soils in this area originated from ancient dry lake beds and volcanic debris. The land here is very fertile and farming is widespread. Warm, sunny days and cool nights are standard for this region year round. Rainfall occurs throughout the year, but the amount increases in the summer. This region generally receives 24 inches per year. These conditions make the temperate region ideal for agricultural production. Production of corn and other food crops as well as sorghum and forage crops are dominant in this area (Bredahl). In this region, the production of beef cattle complements crop production. Cattle are grazed on the mountain slopes that are too steep to plant and crop residues are frequently used in supplemental feeding. Often, cattle are grazed throughout the winter months on crops planted in the fall and after harvest cattle may again graze on the crop residues (Cockerham). Although this region produces one-third of Mexico's beef cattle, dairy production has become very prevalent due to competition for agricultural lands. This region also utilizes dual-purpose cattle or cattle that produce milk and are later slaughtered for their meat (Bredahl).

The most important states for commercial beef cattle are Jalisco, Michoacan, and Oaxaca. These three states are home to 5.604 million head of the 7.7 million head that reside in this region (SAGAR). Livestock occupy more than 18.3 million acres of the temperate region. Due to the fertility of the land, stocking rates in this region are better than in the northern region. The carrying capacity of land in the temperate region can be as good as 1.9 hectares/AU (Soltero-Gardea and Negrete-Ramos). Cattle production is stable in this region even though calving rates did not improve from 1960 to 1991. Calving rates have been only 50-51 percent since 1960 (Arce-Diaz).

Beef cattle breeds vary depending on the region, however there is a high percentage of Zebu-European crosses. Crossbreeds are used in this region due to their adaptability and disease resistance. Generally cattle production in the temperate region is used to satisfy the domestic demand of the nearby population centers. Possible production problems faced by this region are: lack of protein and mineral supplements, scarcity of forages in periods of low water and frosts in higher elevations (Cockerham).

Tropical Region

The tropical region is located around the Pacific and Gulf coasts. This region includes Campeche, Colima, Chiapas, Guerrero, Morelos, Nayarit, Quintana Roo, Sinaloa, Tabasco, Veracruz, and Yucatan (Figure 1.1) (SAGAR). The tropical region could be separated into a wet and a dry region due to the variability in the amount of rainfall. Along the Pacific coast could be considered the drier area, because this area experiences heavy rainfall in the summer and light rainfall throughout the rest of the year. In this drier area, rainfall can total 141 inches per year. In the wetter tropical region at the southern end of Mexico, rainfall occurs year round and may total over 200 inches in some areas. Vegetation varies throughout this region, but forage is abundant in the tropical region. Corn, coffee, cocoa, citrus, and sugarcane can also be found in this region. Rice is typically grown in the wet region while grain sorghum is grown in the dryer area (Cockerham).

The four most important states for beef production are Veracruz, Chiapas, Tabasco, and Sinaloa. These states account for 35 percent of the national beef herd. Beef production has increased at a faster rate in this area than in any other area of Mexico. In 1997 the tropical region was home to over 13 million head of cattle. The cattle in this region account for 46 percent of the national beef herd. This region also contributes 35 percent of the nation's beef, producing 474,269 metric tons in 1997 (SAGAR). In the wet region, it is common to raise Zebu or Criollo on pasture with no supplementation. In the dry region, Zebu, Criollo, and some European breeds such as Hereford or Angus are raised primarily on pasture with some supplementation (Bredahl) Carrying capacity is considered very good in this area with stocking rates averaging 1.0125 hectares per animal unit. This region is considered to have a great deal of high quality forage and calves are more likely to be fattened on grass in this area than in any other region. The tropical area also supports a large number of purebred operations. This beef is generally not consumed locally but instead sent to the Federal District or some other large population center (Cockerham).

Production problems in this region include excessive rainfall and flooding, pests, diseases and mineral deficiencies in the forage caused by leaching of nutrients from the soil. This region has also faced problems with the seasonality of introduced pastures and pastures that lack key elements such as access roads and water supplies. This region is being referred to as Mexico's agricultural frontier. Mexico has determined that these are some of its most fertile lands and they are converting them to higher value crops. But due to a lack of necessary infrastructure and research, it is unclear how fast these lands will be converted to more useful production sites (Cockerham).

Figure 1.1 Climatic Regions of Mexico

Land Tenure

For most of the 20th century, Mexico employed a land tenure system in which peasant communities collectively own agricultural lands. This system of communal land ownership was called *ejido* and the people on these *ejido* lands were called *ejidatarios*. This system was a product of the 1910 Revolution (Valladolid-Chavez). In 1910, 97 percent of the agricultural lands were owned by one percent of the landowners and over 92 percent of the rural population was landless. These large landowners, *hacendados*, employed most of the working class population for wages less the market value and held these employees in servitude through debt accumulation. These landowners also controlled the local markets and credit systems for the area. These were some of the major premises on which the Revolution was based. In 1917, when the Mexican Constitution was drafted, the government established that land had to be distributed to any group of peasants that sought it. Given this constitution the government had the power to expropriate land and constitute new *ejidos*. To protect the *ejidatarios*, the land was prohibited from being sold or rented, furthermore the land could not be owned or managed by a corporation. All labor was performed by *ejidatarios* and their families and *ejidatarios* could only enter into contracts with other *ejidatarios* with government approval.

Although this law was written in 1917, it was not until 1940 that much of the land was distributed to the peasants so that they owned 50 percent of the cultivated land (Valladolid-Chavez). These Agrarian Reform Laws also limited the size of private landholdings (Heath). Landholdings for cattle ranchers were limited to the amount of land that could support 500 head of cattle or an equivalent number of smaller livestock.

Crop cultivation and cattle ranching were seen as two totally separate activities and therefore they were not allowed to co-exist on the same property. By defining the size limitations in terms of carrying capacity and by prohibiting crop cultivation on the same land, farmers had no incentive to improve their lands for fear that it would be reclassified and expropriated. With these agricultural policies there was disincentive for improving the quality of lands in the private sector (Heath).

Table 1.1. Land Tenure and Land Use for Cattle Production by Region in Hectares

Regions	*Ejido* Land Area	*Ejido* Land for Cattle	Private Land Area	Private Land for Cattle
Arid/Semiarid	51,504,820	15,966,494	60,911,940	44,343,892
Temperate	18,877,304	5,851,964	17,488,272	12,731,462
Tropical	92,678,328	6,911,823	21,543,434	15,683,620

Sources: Heath.

In 1990, over 3 million peasants were registered as *ejidatario* members in 28,058 *ejidos* throughout Mexico. If it is assumed that the average family size is six people, then as many as 18 million people, or 21 percent of the population, were living on *ejidos*. Although 85 percent of the *ejidatarios* have access to small land plots, almost 75 percent of all *ejido* lands were held in common. This means that the *ejido* lands were farmed by all the *ejidatarios* having access to them. Basic infrastructure was severely lacking in most *ejidos*: One-third of *ejidos* did not have electricity, less than half of the *ejidos* had access to potable water, and only 20 percent had access to paved roads (Thompson and Wilson)

There were four essential differences between the *ejidos* and private land holdings (Heath). The first was that the *ejido* parcels belong to the nation; the *ejidatarios* may neither sell nor mortgage their property. Second, it was not uncommon for *ejido* parcels to remain in the same family for generations but the government could confiscate the land if it was thought to be abandoned or illegally leased out. Third, the *ejido* parcels may not be divided among heirs but they must be passed to single households intact. Fourth, *ejidatarios* were granted free access to communal grazing and forest lands belonging to the *ejido*. These differences between private and *ejido* lands suggested that *ejidatarios* were less likely to invest in the land than private farmers. This was due to two reasons. The first was that if an *ejidatarios'* land was confiscated or if they left the parcel voluntarily they would receive no compensation for any improvements made to the land. The second reason was since *ejidos* rarely organize communal funds there were no resources aimed at conserving or upgrading their lands. There was no policy mechanism to fine users for resource depletion in *ejidos*, these lands were more likely to be overgrazed (Heath). A study by Yates found that large private farms were more than 50 percent more productive, in terms of pesos per hectare, than *ejido* farms in crop and livestock production. Although there was some argument as to the differences in the quality of *ejido* and privatized lands, there was substantial evidence that *ejido* lands were prone to the problems of public goods. Since these lands do not have defined property rights there was little incentive to conserve or improve their resources.

Article 27 of the Mexican Constitution was amended in January of 1992 to facilitate the modernization of Mexican agriculture. This law set forth many new provisions:the redistribution of land through expropriation was prohibited; peasants no longer had the right to petition for land; parceled communal lands could be rented or sold to other farmers; and corporations can own land. This law was passed to encourage investment and productivity gains that may only be achieved through developing economies of size. President Salinas de Gortari argued that this reform could help Mexico increase productivity so that the nation could compete with other countries (Valladolid-Chavez).

This research considered the land tenure system that has existed in Mexico for most of the 20th century. The *ejido* lands have not disappeared due to the 1992 change in the Mexican constitution. *Ejidatarios* still live and farm as they have for many years. One of the main reasons for recognizing the land tenure system in this research was that cattle production on *ejido* lands differs greatly from production on private lands. Some of the differences are in the quality of grazing land, the availability of high quality forage, the average herd size and in the type of cattle raised.

Overview of the Mexican Cattle Industry

The cattle industry in Mexico is characterized by many aspects that make its production very different from that of the United States. The land tenure system in Mexico has had adverse affects on cattle production in the sense that policy has limited this industry. Due to the restrictions on land use and the limitation of owning only enough land to support 500 animals, Mexico has been unable to develop large cattle operations. This industry has been restricted in its growth and therefore limited in its ability to benefit from economies of size in the cattle industry. Due to a history of limited grazing land in the *ejido* lands, cattle production has been much more important to the private and the mixed land owners (Gonzalez-Padilla). The average herd size for producers on private and mixed lands is much larger than for those producers using *ejido* land. In the private sector the majority of the cattle were in herds that were from 100 to 1,000 head. In the *ejido* sector, the majority of the cattle were in herds of five to 20 head

These characteristics demonstrate the differences in the nature of production between the private and *ejido* sectors.

Cattle in Mexico were broken into three different categories according to the *VII Censo Agricola Ganadero de 1991* (Seventh Agricultural Livestock Census of 1991). Cattle are categorized as *Corrientes* (Local), *Fino* (Purebred) or *de Cruza* (Crossbred). *Corrientes* can be defined as "common cattle" or "cattle of the country " "*Corriente*" cattle are also referred to as *Criollo* or *Chinampo*. In Mexico, the term "*Corriente*" is a term frequently used to refer to any small cattle of indiscriminate breeding (OSU Animal Science Department "Corriente."). These cattle can not be defined by a breed or a group of breeds due to the nature of their existence *Corriente* cattle are a mixture of many breeds that has been developed throughout time. These cattle are recognized for their disease and pest resistance as well as for being tolerant of extreme heat. They are considered small framed cattle with light muscling but their forage requirements are minimal and they can live in the most desolate of conditions (Bredahl, Burst, and Warnken).

Fino or Purebred cattle are those cattle that are defined by their breed or pedigree. This group of cattle has expanded in Mexico due to the steer export market that exists between the U.S. and Mexico. Therefore, many of the purebred cattle that are raised in Mexico are cattle that the U.S. market demands. Some of the most common purebreds found in Mexico are Hereford, Angus, Charolais, and Santa Gertrudis (Bredahl, Burst, and Warnken). *De Cruza* or Crossbred cattle are those cattle that are the products of crossbreeding two separate purebreds or by crossing purebred and *Corriente* cattle. Crossbreeding is often used to capture the positive characteristics of two breeds in one offspring. Each region of production in Mexico has a mixture of all types of cattle but some types of cattle are dominate in certain regions. Table 1.2 provides a subdivision of cattle by type for the three different production regions of Mexico (INEGI).

Table 1.2. Distribution of Cattle by Type in the Production Regions of Mexico

Regions	Total Inventory	*Corriente* Inventory (hd)	(%)	*Fino* Inventory (hd)	(%)	*De Cruza* Inventory (hd)	(%)
Arid/Semiarid	8,935,752	2,200,023	24.6	3,015,397	33.7	3,720,33	41.6
Temperate	6,269,271	2,430,539	38.7	1,674,872	26.7	2,163,86	34.5
Tropical	8,660,876	2,431,423	28.0	2,164,781	24.9	4,064,67	46.9
Total	23,865,899	7,061,985	29.6	6,855,050	28.7	9,948,86	41.7

Source: INEGI.

The distribution of the different types of cattle can explain many of the variations between the production regions. A larger percentage of *fino* cattle are in the arid/semiarid region. This is due to its close proximity to the United States and the large export market that drives the cattle market in this region Cattle production in this region has evolved to fit the demand of the United States market. The temperate region has a larger percentage of *corriente* cattle. This is logical since this area has many rich and fertile farmlands and the focus in this area is agricultural crop production. *Corriente* cattle are often grazed on steep mountainsides or on crop residues A strong dairy industry in this area is responsible for many of the *fino* and *de cruza* cattle. The tropical region has the highest percentage of *de cruza* cattle of the three regions. This is due to the higher performance of crossbred animals in the tropical environment. Crossbreeding between the *corriente* and *fino* cattle is often used in this region to produce cattle that are heavily muscled while still being resistant to diseases and pests (Bredahl, Burst and Warnken)

For the purposes of this model the purebred and crossbred cattle were combined into one group designated "introduced" cattle. While the *Corriente* cattle will be called "native" cattle. Throughout Mexico the private sector owns more of the introduced cattle than does the *ejido* sector (INEGI). While 71 percent of the herd in the private sector are introduced cattle only 56 percent of the cattle on *ejido* land are introduced (Appendix Table A.2.). This is significant when considering the differences between the two sectors and examining the role of each sector in the Mexican cattle industry in the future.

A unique aspect of the cattle industry in Mexico is the practice of using cows for a dual purpose. Dual purpose cows are used for milk as well as beef production. Dual purpose cows are used to produce milk for the family as well as calves that will later be sold into the beef cattle market. These cows produce approximately three quarts of milk per day and have a lactation period of 60 to 180 days. Breeds that are likely to be crossed and used for dual purpose production include Brahman, Brown Swiss and various Zebu breeds (Cockerham). According to the Mexican Livestock Census of 1991, about 40 percent of the cows in Mexico were titled as dual purpose animals. This aspect of the Mexican production system is useful for those families who might not have access to the necessary infrastructure to obtain valuable dairy products. Although this practice may reduce the productivity of these cows for producing beef calves, dual purpose cows are utilized in small operations and are generally not found in commercial or purebred cow-calf operations (Cockerham).

Calves from the dual purpose cows and other beef cow operations are typically sold to either "growing-fattening" producers or intensive feed stockyards (U.S. Meat Export Federation, et al.). Calves that go to extensive fattening operations are placed on pasture until they are finished. Generally these operations use a rotational pasture procedure to help avoid overgrazing and depletion of the natural resources. Due to a low rate of gain, these calves spend from two to three years on pasture finishing depending on the availability of quality forage. Calves purchased by the intensive feed stockyards are fattened using grain rations. These operations are very similar to U.S. feedlots but differ in the types of grains they feed. Their focus is to fatten calves with various grain rations in a very short period of time relative to those extensive producers. These intensive feeding yards are concentrated in the northern region of the country. After these calves have been fattened whether it be on grass or with grain, they are sold to a middleman or directly to the slaughter facility. Figure 1.2 illustrates the system of commercialization channels in the Mexican cattle industry (U.S. Meat Export Federation, et al.). There are various types of middlemen throughout Mexico's cattle industry that facilitate the transfer of cattle from one step in the process to the next.

Figure 1.2 Commercialization Channels for Livestock

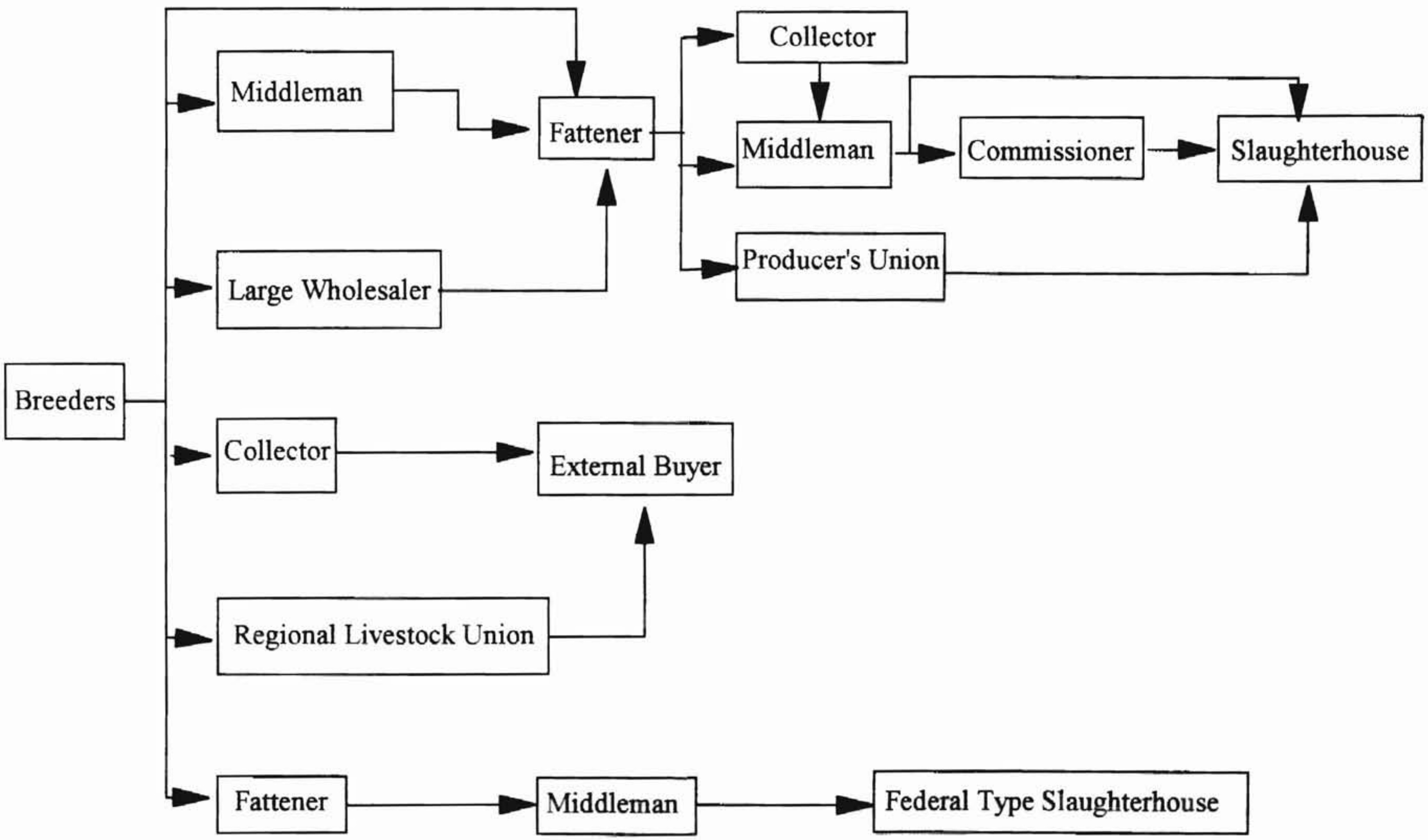


Figure 1.2. illustrates the commercialization channels that exist in the Mexican cattle industry to market livestock (U.S. Meat Export Federation , et al.). There are many intermediaries in this process of getting calves from the breeder to the slaughterhouses. A middleman is defined as the person that buys live cattle and then controls the volume of slaughter and the commercialization of slaughter products. A collector gathers calves from small and medium producers and then puts them in uniform groups to sell to a middleman or an external buyer. A fattener, who feeds either grain or pasture, buys calves at about 180 kilograms to fatten to 400 kilograms. The producer's union replaces the middleman in their function of selling to the slaughterhouses. These intermediaries interfere with the production process and rob breeders and fatteners of profits (U.S. Meat Export Federation, et al.).

Slaughter and Beef Production Industry

The slaughter industry in Mexico is different in many aspects from the U.S. industry. The Mexican livestock slaughter industry is made up of two separate entities. The *municipales* (municipality-owned slaughterhouses) handle the majority of the cattle slaughter in Mexico, although in recent years there has been an increase in slaughter at *Tipo Inspeccion Federal* (TIF) plants (SAGAR). Municipal slaughterhouses provide the basic infrastructure that supplies the majority of meat products to the Mexican consumer (U.S. Meat Export Federation, et al.). These plants are not specific to cattle, hogs or chickens but rather are capable of slaughtering all livestock. TIF plants are more similar to plants that exist in the United States. These plants were built in anticipation of meat export demands in the 1970s. They are built under strict construction regulations and operated under strict sanitary and high efficiency standards. These plants are designed to slaughter one species of livestock with the exception of a few being designed for cattle and hogs simultaneously (U.S. Meat Export Federation, et al.). These differences between the *municipales* and the *Tipo Inspeccion Federal* plants make the Mexican slaughter industry unique in many instances.

Slaughter rates were expected to increase in May of 1999 as compared with May of 1998, although TIF production capacity has not increased in response to this estimated increase. The USDA estimates that only 20 percent of Mexican beef and pork was processed in TIF plants in 1998 Some of the non-TIF plants are rebuilding so that they can export to the United States market. There are 12 non-TIF slaughter houses located in the Mexico City metropolitan area that continue to operate as municipal slaughterhouses The government no longer intends to close these facilities because of the inability of the TIF plants to supply the Mexico City area (USDA/FAS). SAGAR confirms that there are no TIF plants in the Federal District and the surrounding states. The closest facilities to Mexico City that are federally inspected are in Jalisco or Veracruz.

TIF Slaughter Facilities

According to SAGAR, eighty percent of Mexico's cattle are slaughtered in locally inspected municipal slaughter facilities. Although the TIF plants have made an incremental increase in market share, they have been slow in their ability to capture a larger percentage of the slaughter market. The main reason is that they face higher costs than other locally regulated slaughter facilities. Cost of slaughter is 30-50 percent less in locally inspected plants than in the federally inspected plants. The TIF plants have higher costs due to the stricter sanitary conditions, the humanitarian practices used in slaughter and the capability of these plants to store and transport meat in refrigerated conditions.

Table 1.3 includes a state breakdown of TIF slaughter facilities. It illustrates where the majority of the slaughter activities occur. This infrastructure supplies both the domestic market and the export market. Twenty-nine of the 39 TIF plants are properly managed and inspected to fulfill the requirements necessary to export meat to Japan, the U.S., Canada, and the European Union (SAGAR).

Table 1.3. Municipal and TIF Slaughterhouses in the Sates of Mexico

State	Number of Municipal Slaughterhouses[2]	Number of TIF Slaughterhouses[1]
Arid Region	113	23
Baja California	4	2
Baja California Sur	2	0
Coahuila	12	2
Chihuahua	12	4
Durango	7	1
Nuevo Leon	9	3
San Luis Potosi	19	0
Sonora	18	5
Tamaulipas	16	4
Zacatecas	14	2
Temperate Region	142	5
Aguascalientes	4	1
Distrito Federal	3	0
Guanajuato	29	0
Hidalgo	10	0
Jalisco	25	2
Mexico	13	1
Michoacan	18	0
Oaxaca	14	0
Puebla	15	1
Queretaro	6	0
Tlaxcala	5	0
Tropical Region	116	11
Campeche	5	0
Colima	3	0
Chiapas	16	3
Guerrero	15	0
Morelos	5	0
Nayarit	5	0
Quintana Roo	2	0
Sinaloa	9	2
Tabasco	14	1
Veracruz	38	4
Yucatan	4	1

Source: [1] SAGAR, and [2] U.S Meat Export Federation, et al

There are 39 TIF plants specialized in beef processing in Mexico. These slaughterhouses have the capacity to process 2.9 million head per year. They slaughtered 1.3 million head in 1997. This represents only 45-50 percent of their total capacity. If these facilities were to utilize their full capacities, then they could slaughter 45-50 percent of Mexico's existing slaughter market (SAGAR). Table 1.4 illustrates the installed capacity and the utilization of the federally inspected slaughter facilities for these states.

Table 1.4. Installed Capacity and Utilization of Federally Inspected Slaughter Plants

State	Current Utilization (head/yr)	Installed Capacity (head/yr)
Aguascalientes	38,000	90,000
Baja California	130,000	205,000
Coahuila	50,000	170,000
Chiapas	56,000	175,000
Chihuahua	85,000	200,000
Durango	25,000	52,000
Jalisco	60,000	95,000
Nuevo Leon	220,000	395,000
Puebla	0	5,000
San Luis Potosi	38,000	70,000
Sinaloa	130,000	180,000
Sonora	100,000	318,000
Tabasco	175,000	375,000
Tamaulipas	85,000	225,000
Veracruz	180,000	245,000
Yucatan	38,000	100,000
Zacatecas	5,000	75,000

Source: SAGAR.

Municipal Slaughter Facilities

TIF plants process approximately 20 percent of Mexico's national beef production. Municipal slaughterhouses vary in terms of their working capacity because they range in size and technology level across the country. But it is evident that in general, they are smaller in terms of the animals they are capable of slaughtering. The average Municipal plants is smaller than TIF facilities in terms of the capacity of animals that can be processed per day, with Municipal plants processing 120-150 head per day while the TIF plants are capable of slaughtering up to 180 head per day. Equipment and buildings in the Municipal facilities are generally very old and storage in some facilities is not possible. However, some of these facilities have been remodeled and equipped according to the provisions for the TIF facilities but they lack the inspection and approval of the *Secretaria de Agricultura y Recursos Hidraulicos* (Department of Health and Hydraulic Resources). There is only state mandated food safety inspection in these Municipality-owned slaughter plants. These plants supply the meat products in traditional cuts for the Mexican population through the local markets. While TIF plants focus on producing "American type cuts" that will be sent to supermarket chains as well as hotels and restaurants (U.S. Meat Export Federation, et al.).

Beef Products

Two distinct types of beef are produced by the Mexican cattle industry: fed and non-fed beef. Fed beef is the product of calves that have been finished in some type of intensive management system with grain rations. It is considered a higher quality beef that is designated as marbled. Non-fed beef is that beef derived from calves that are fattened in extensive operations. Since these animals are grass-fed throughout their life, they are slaughtered at two to three years of age. This beef contains less fat and is leaner than fed beef products. Beef products processed in larger municipal facilities and TIF facilities are classified into quality grades according to the condition and muscling of the calf. Meat products can be graded into five separate categories: Mexico Extra, Mexico 1, Mexico 2, Mexico 3, and Out of Classification. This grading procedure is based on the visual appearance of the carcass according to eight separate criterion: conformation, muscular tissue, loin, side view of the rib, side view of the croup, side view of leg, hip bone, and finishing. These criteria are set so that cattle must be properly fattened to grade in the Mexico 1 or Mexico 2 categories. The top grade of Mexico Extra is achieved only by specialized animals that are extremely finished This grading system also specifies minimum weight requirements for calves so that they can grade at a certain level. Steers must weigh 360 kilograms (793.8 pounds) to grade in a Mexico 2 or 375 kilograms (826.88 pounds) to grade in the Mexico 1 category. While cows and bulls grade into the Mexico 2 category only if they weigh 280 kilograms or 617 pounds, all lighter cows and bulls are put in lower grades. This grading system provides some basis for the classification of meat in the Mexican industry (U.S. Meat Export Federation, et al.).

Commercialization of Beef

Throughout history meat products have been purchased from two types of traditional markets. *Mercados* are permanent covered neighborhood markets, that have individual stalls for merchants selling beef, poultry, cheese, fruits and vegetables. *Tianguis* are roving outdoor markets that sell a wide range of products and move from one neighborhood to the next on designated days of the week (USDA, 1994). Recently supermarkets have entered the food market in largely populated cities. These larger supermarket chains have integrated with the TIF slaughter plants to provide consumers with beef products that are similar to the kind of cuts seen in U.S. supermarkets. The TIF slaughterhouses send meat to an external market or a wholesaler, from the wholesaler these beef products are then sent to a supermarket to be marketed to the consumer. Municipal slaughterhouses produce directly for the non-supermarket retail industry These retailers are responsible for further processing or piecing out the carcass and then marketing it to the consumer Since these retailers are responsible for cutting the carcass into the final consumer product there is a great deal of variation in the cuts of meat that are marketed.

Consumption

Demand for beef products will determine the prosperity and production of the Mexican beef industry. There is a significant demand for beef products in Mexico. Mexico's economy averaged six percent growth in 1996 and 1997 and is expected to continue strong growth. Economic growth in Mexico will support increases in beef consumption (Lawrence). Meat consumption patterns in Mexico are the result of the interactions of price, income levels, product availability, and cultural factors (Rosson, et al.). According to Peel, there has been an overall increase in the demand for beef in terms of quality and quantity. An overall increase in population as well as an expanding middle class of workers has increased demand for a higher quality source of protein (Peel).

Population

In 1995 the estimated Mexican population was 91.1 million. The population growth was estimated to be 1.9 percent annually. Thus, the population is expected to reach 100.1 million by the year 2000. This rate of growth is considered relatively high for a developed country. This population is also very young with 70.8 percent of Mexico's residents being under the age of thirty. The geographic composition of the population has experienced vast changes in the last forty years with seventy percent of the current population now considered urban dwellers. Nearly half of this urban population lives in the three largest cities: Mexico City, Guadalajara, and Monterrey.

Income Distribution

The income level of consumers will greatly impact their ability to purchase beef. Beef is considered somewhat of a luxury good for Mexican consumers due to high prices and the accessibility of substitute products. Table 1.5 includes the population categorized into four social classes based on existing income distribution patterns.

Table 1.5. Mexican Population Stratification by Socioeconomic Income Levels

Group Stratification by Social Class	Household Composition	Percent of Total Population	Monthly Household with Income Ranges (U.S. $)
Upper Income	2,733,613	3	$5,000 +
Upper Middle Income	10,023,248	11	$1,500-4,999
Lower Middle Income	22,780,108	25	$500-1,499
Lower Income	55,583,464	61	$120-499
Total	91,120,433	100	

Source: USDA, 1999a.

The upper income class constitutes the elite of Mexican society. The upper middle class includes working professionals and small business owners. The lower middle class is made up of blue collar workers, retail clerks, and minimally skilled laborers. The lower class lives in extreme poverty by U.S. standards. Income distribution plays a large role in the consumers' ability to purchase beef products. The upper class demands and can afford premium-priced carcass cuts from the United States. While the lower class are more likely to eat less meat (USDA "Exporting U.S. Red Meat and Poultry Products to Mexico in a Free Trade Environment").

The U.S. Meat Export Federation, the Texas Beef Industry Council and the Kansas Beef Council present a different socioeconomic division of Mexico's population. They divide the population into five categories according to income level. The first two levels, A and B, include the portion of the population with incomes 16 to 30 times above that of the minimum salary. These segments set the consumption and cultural patterns that are followed by the rest of the population even though, these segments represent only five percent of the total population. Level C is the middle class and it is considered the bulk of the consumer market with 30 percent of the population in this category. Average salaries in this category tend to be 5 to 6 times greater than the minimum salary. This population is most likely to follow the consumer patterns of the A and B level, but these purchases may be economically out-of-reach for this population. The two lowest socioeconomic levels in the characterization are levels D and E, these levels comprise 65 percent of the total population. The level D population can be distinguished from the level E population because they have a fixed income that is one to three times greater than the minimum salary. This allows them to set some consumer patterns. This segment is where the largest percentage of the population is located. The level E segment of the population has an income below the minimum salary required to develop set consumer market patterns (U.S Meat Export Federation, et al.)

These socioeconomic aspects of the population in Mexico are very important when considering the current beef consumption. In 1999, per capita beef consumption in, terms of carcass weight, was 45 pounds per year, which is about 46 percent of the U.S level of 98 pounds per year (Lawrence). Income is an overwhelming limitation to beef consumption when 65 percent of the population is considered to live on incomes below the minimum salary requirements. Free trade between the U.S. and stabilization of the peso has encouraged economic growth in Mexico. While Mexico's population is growing rapidly, the middle class section of their population is also growing steadily. This growth in the middle income class has increased the beef demand in terms of quantity and quality (Peel).

CHAPTER II

LITERATURE REVIEW

Since the implementation of NAFTA, the relationship between Mexico and the United States has been the focus of various studies. Segarra presents the impact that NAFTA will have on Mexico and its agriculture sector. Trade between Mexico and the United States is very important to Mexico, since 70 percent of Mexico's imports are from the U.S. and 70 percent of Mexico's exports go to the United States. This relationship is even more important in agriculture, because 95 percent of Mexico's agricultural exports are sent to the United States, and 75 percent of Mexico's agricultural imports are received from the U.S (Segarra). NAFTA will facilitate trade between the U.S., Canada and Mexico due to the complementarity of their agricultural production. But in the long run, structural changes will be internalized by the countries, and some degree of specialization or increased competition in specific sectors of agriculture will result. Mexico was encouraged to implement freer trade as a means to improve their agricultural productivity through increased competition.

Segarra used Vollrath's relative trade advantage measure. Vollrath's trade measure evaluates how well a country's particular commodity competes for resources with other sectors domestically and globally. Using Vollrath's measure, the U.S. and

Canada have a relative trade advantage over Mexico in the dairy products market, coarse grains, wheat, oilseeds, and the meat and livestock products market (Segarra). While Mexico has a trade advantage over the United States and Canada in fruits, vegetables, coffee, cocoa, tea, and spices (Segarra).

Melton and Huffman as well as Kennedy and Hughes agree that free trade flows between the United States and Mexico will advance the technology level in Mexico's cattle industry. They agree that due to technology transfers the efficiency of production will increase therefore increasing total cattle production in Mexico. The objective of the Kennedy and Hughes study was to quantify the welfare effects of an agricultural free trade agreement. Kennedy and Hughes conclude that Mexico and the U.S. will both be better off if they focus on achieving agricultural free trade with one another. They believe this would benefit both agricultural sectors as a whole and eventually increase overall trade flows between the two countries Kennedy and Hughes also conclude that due to an increase in the production of beef cattle by Mexico, the U.S. producer price for fed cattle will decrease. The authors conclude that although certain sectors in each economy will suffer, overall NAFTA will result in a welfare gain.

The effects of NAFTA will extend beyond trade, so that the barriers to capital investment and technological trade will dissolve as well Melton and Huffman used this assumption to analyze the long-run effects of NAFTA on beef production and processing. They assumed that Mexico is able to adopt the technology, capital investment, and infrastructure that are available in the U.S. The authors conclude that, Mexico would dramatically increase the size of their cow herd. This results from the assumption that Mexico will expand its cattle supply and will have lower post-slaughter processing cost

Although a majority of the necessary feed grains for cattle production would be imported from the U.S., Mexico would develop a comparative advantage in calf production. They conclude that the size of Mexico's cow herd will increase given Mexico's comparative advantage in low-skilled, labor-intensive industries. These conclusions follow from the assumptions. One being that Mexico's available resource base is comparable to that of the United States. The authors also assume that Mexico has the infrastructure to support the technology of today's packing and slaughter industry. Melton and Huffman did not address transportation issues which may be very important in the development and success of the cattle and slaughter industries in Mexico.

Burfisher, House, and Langley reviewed nine different studies on the impact of a free trade agreement with Mexico. These studies included partial and general equilibrium models and multisector macroeconomic analyses. They found that overall, the effects of a free trade agreement are expected to be small on the total United States farm output. They suggest that total U.S. agricultural output will increase due to an increase in Mexican demand. However, they note ambiguity in their two free trade area scenarios specific to live cattle production. One estimates a decline in U.S. imports of 2.4 million hundredweight and the other estimates a rise in imports of 5.3 million hundredweight. This translates to an impact ranging from a 1.1 percent rise to a 3.1 percent decline in total U.S. production (Burfisher, et al.)

Cockerham estimated the historical impact of imported feeder cattle on the U.S. market and evaluated the potential effect of NAFTA on the U.S. feeder cattle market. She concluded that the economic impact of NAFTA will be small in the U.S. feeder cattle market. Historically the number of cattle imported from Mexico has been a very small percentage of the total number of cattle on feed in the United States and assumes that this trend will continue. Using a price flexibility, it was determined that the decrease in price due to a 1,000 head increase in quantity imported would only be $.02 per hundred weight. Cockerham noted that her study was limited due to the difficulty in estimating the number of cattle that would be imported from Mexico

Rosson et al. investigated the impact of NAFTA on the United States-Mexico meat trade. They used price and income elasticities to determine the potential change in Mexico's demand for imported meat given the free trade situation They assume that the United States will dominate the Mexican import market due to the reduced trade barriers. The import demand elasticity calculated for beef was -75.66, meaning that for every 1% decrease in the domestic price of beef in Mexico there would be a 75.66% increase in beef imports. The authors point out that the import demand elasticity appears very large and describes a very elastic demand curve. They argue that this is due to the fact that the U.S. beef imports account for only a small portion of total beef supply in Mexico. They assume that the domestic price of beef in Mexico will decrease given a greater quantity of beef available. The authors rationalize that the U.S. will have to import or produce a greater quantity of cattle to satisfy the growing import demand of Mexico. They concluded that the main constraints to freer trade between the U.S. and Mexico appear to be nontariff barriers, including U.S. policies that affect feed grain prices and domestic policy in Mexico that subsidizes producers through inputs such as feed grains, land, credit, and energy. In the short-term, they expect an increase in feeder cattle exports to the U.S. and an increase in U.S exports of beef. However, in the long-term freer trade could encourage the development of a stronger Mexican beef industry (Rosson et al.).

The research mentioned above has attempted to estimate the changes in the Mexican cattle industry given freer trade between the U.S. and Mexico. Through all of this research there has been little emphasis on the current resource base of Mexico and the condition of those resources. The focus of this research is to determine the possible changes in the production and slaughter of beef cattle in Mexico. This research is justified because it takes into account Mexico's available resources, the productivity of its herd, and the changing demand of the Mexican consumers.

CHAPTER III

DATA AND PROCEDURES

Data

Land Tenure

Thompson and Wilson determined the amount of land area that is classified as *ejido* and private in Mexico per state. These authors report the area of land that is *ejido* and the *ejidos* as a percentage of total state land area. This allows for the calculation of private land per total state land area (Refer to Appendix Table A.6). After finding the area of *ejido* and private land for each of the three regions, it was necessary to determine the amount of land of each type used for cattle production. Heath offers a breakdown of land use by tenure category. Table 3.1 includes land use according to *ejido* or private ownership.

Table 3.1. Land Use by Tenure Category

	Ejido		Private	
All Farms	1,000 ha	(%)	1,000 ha	(%)
Total	15,235	100.0	73,862	100.0
In Production	12,975	85.2	54,200	73.4
Cultivated	8,279	54.3	8,753	11.8
Fallow	1,733	11.3	1,675	2.2
Natural Pasture	2,154	14.1	27,427	37.1
Forest	2,588	16.9	26,426	35.7
Other	481	3.1	9,599	12.9
Irrigated	1,878	12.3	9,133	12.3

Source: Heath.

It was assumed that cattle production takes place on land categorized as natural pastures and on forest land. Under this assumption, thirty-one percent of *ejido* land is used for cattle production, while 72 percent of private land is used for cattle production (Heath). It was assumed that this is the case in all regions of production By determining the percentage of land that was used for cattle production in the social and private sectors and the total quantity of *ejido* and private land per region in Mexico, it was possible to determine the amount of *ejido* and private land used for cattle production.

Large amounts of data used in this linear programming model were taken from the *VII Censo Agricola Ganadero de 1991* or the Livestock Census of 1991 This census is conducted by INEGI (*Instituto Nacional de Estadistica, Geografia e Informatica*) and it characterizes the Mexican cattle industry in many different ways. All of these data were provided on a state level with the breakdown of urban and rural production, furthermore, the rural production is broken into private, *ejido* and mixed types of ownership (INEGI) These state level data were then combined to reflect the three production regions used in the model Private ownership in Mexico is when there is one specific owner of the property and the property rights of that individual are defined. *Ejido* lands are community owned lands that are available for use by any of the assigned community members. These lands are officially government property. The land category entitled "Mixed Lands" includes landowners that own private lands and also utilize *ejido* lands. These mixed lands are a considerably small percentage of the land and they exhibit qualities much like the private-owned lands (Gonzalez-Padilla). Padilla reports that cattle ownership is more important in private and mixed properties. Census data confirm this finding. In general, the mixed properties had the same average herd sizes as the private properties (INEGI). For these reasons, the mixed lands were categorized with the privately held lands and considered private.

Cattle Types

The census compiled one of the databases of cattle by type, cattle being *Corrientes, Fino, or De Cruza*. This translates to local cattle, purebred cattle and crossbred cattle, respectively. *Corriente* cattle are local breeds that are raised throughout Mexico. Purebred cattle are the species that have been introduced into Mexico. They are typically various European breeds. Crossbred cattle are the product of breeding two different purebred cattle or purebred and *Corriente*. For the purposes of this research the purebred and crossbred cattle were combined into one group to represent introduced cattle. The *Corrientes* were considered a separate group of cattle that represents the native cattle of Mexico. Justification for the groupings of these cattle is that it is important to show the role of the native cattle verses the role of the introduced cattle.

Stocking Rates

The relative stocking rates for the three regions of production are still uncertain. This is mainly due to the large area of the regions and the various types of forage that cover these production regions. Preliminary stocking rates were calculated using data from the *VII Censo Agricola Ganadero de 1991* (Seventh Agricultural Livestock Census of 1991). The census database provided the number of farms and the inventory for each cattle type by the size of farm according to improved pasture and hectares of natural pasture. These state level data were compiled into the three regions and used to calculate stocking rates for the different types of cattle in each region. These data do not provide any information on the land area that was in improved pasture. Hence, the stocking rates do not reflect the number of cattle on this pasture type. Since the farms using natural pasture were broken into size subdivisions, approximate stocking rates for these farms could be calculated. Based on the census data, the average farm size varies greatly between the *ejido* and privately owned farms. Stocking rates for private and *ejido* production were estimated with the data from the farm size category with the highest population of cattle. On the privately owned land, those farms with 100-1000 hectares contained the most cattle. On the *ejido* land, those farms with 5-20 hectare contained the most cattle. Stocking density was estimated for the native and the introduced cattle groups for each region according to the type of ownership in which they were managed (INEGI).

Table 3.2. Estimated Stocking Density

Regions	Native Cattle Ha/hd	Introduced Cattle Ha/hd
Arid/Semiarid Region		
Private Land	12.3279	6.4522
Ejido Land	.9931	.7241
Temperate Region		
Private Land	15.6738	6.9496
Ejido Land	1.1995	0.7337
Tropical Region		
Private Land	7.3338	4.5222
Ejido Land	1.1317	.8519

Source: INEGI.

Stocking densities were estimated by determining the average number of cattle per farm and then dividing that by the average number of hectares per farm, which was 550 hectares for private production and 12.5 hectares for *ejido* production.

(3.1) SD = Cattle Inventory/ Units of Production /Average Hectares per Unit of Production

These estimates have many limitations, and therefore they were used as a relative guide for determining actual stocking rates but they were not used in the model. These estimates fail to account for the distribution of the farm sizes in each size grouping. It simply uses the average number of hectares in that specific size group of farms. This method of estimation determines that the *ejido* lands consistently have a much higher stocking density than the private lands. These lands are owned in common by the *ejidatarios*. Due to the nature of production on *ejido* land these stocking rates are very misleading. Often cattle are kept by subsistence farm families and fed crop residues or other various "leftovers." Cattle might be kept in the backyard and then grazed on *ejido* lands or other community property during the day. *Ejido* lands are public goods. There is little economic incentive to conserve these resources and very often the land is severely overgrazed. The other apparent issue that arises from these estimates is that in all regions, the native cattle are allocated more hectáres per head than the introduced cattle. This seems counter intuitive. Native cattle are smaller bodied cattle that require less forage for their maintenance and reproductive health. While the larger bodied improved cattle need greater quantities of higher quality forage. The likely explanation for this is that native cattle are typically raised in areas that will support little else except these cattle. They are typically produced in mountain or dessert areas that contain little forage and are unusable for crop production. In some areas native cattle may be grazed on crop residues from land that is primarily used for other crop production.

Table 3.3. Stocking Densities used in Model

Regions	Native Ha/hd	Improved Cattle Ha/hd
Arid/Semiarid Region		
Private Land	5	5.3
Ejido Land	4	4.5
Temperate Region		
Private Land	5	6
Ejido Land	3	5
Tropical Region		
Private Land	4	4.5
Ejido Land	1.5	2.5

The stocking rates reported in Table 3.3 were used in the mathematical programming model. For the aforementioned reasons it was necessary to adjust the stocking rates. These stocking rates still observe the pattern presented in the stocking rates calculated using census data. Those cattle on *ejido* lands are allocated less land per head than those animals on private lands. This is thought to be true due to the nature of production on these *ejido* lands and the nature of feeding cattle on these lands. These estimations assume that all hectares have the same type and quality of forage for cattle consumption. The model also assumes that all forage has the same relative cost. That is to say that actual productivity of the land across regions may vary, but the relative costs are the same.

In this model all land is assumed to have an equal value when productivity is taken into consideration. Private land is assumed to have a relative cost of $60 per animal unit and *ejido* land is assumed to have a relative cost of $40 per animal unit. For example, if one native animal unit requires 5 hectares of land in the arid region then the cost of forage for that animal unit is $12 per hectare. The same is true with the ejido land, if one native animal unit requires 4 hectares of land in the arid region then the cost of forage for that animal unit is $10 per hectare (Appendix Table A.10.).

Cow Productivity

To calculate cow productivity rates, it was necessary to determine which data would best represent the two groups of cattle in the model The weaning weights for the native cattle were determined using an average of the productivity rates for the Commercial Zebu, Brahman, Indubrazil, and Gyr breeds (Magna and Segura). The weaning weights were determined by averaging the average daily gain of the four breeds and then taking that times 205 days and then adding the average birth weight. This estimate was used for two reasons. The first reason is that these breeds are typical of the Corriente population in Mexico The second reason is that Magna and Segura conduct their research in south-eastern Mexico which indicates that their findings represent a more accurate picture of the animal's growth characteristics in Mexico's environment (Magna and Segura).

Weaning rates for each set of cattle were estimated by using the following sources and adjusting those rates according to each region's production characteristics. The weaning rates for introduced cattle were taken from a study conducted by Reynolds, DeRouen and Kooncein in the Gulf Coast area of the United States. For the native cattle, four estimates for Criollo and Guzerat cattle were consulted to provide a basic weaning rate (Montano-Bermudez). Preferably both the weaning weight estimate and the weaning rate estimate would have been obtained from the same research. But, that was not the case. The Montano-Bernudez reported weaning weights but did not indicate the number of days at which the calves were weaned. Since these weaning rates were not differentiated by region; the rates were adjusted according to the region of production.

It was determined that the productivity measures for Brangus would be used for the introduced cattle in this model. The Brangus breed is 3/8 Brahman and 5/8 Angus, solid black and polled (OSU, 1999a). There are many reasons for choosing this particular breed to represent the introduced cattle. The Brangus breed is well recognized in the United States and in Mexico. The Brahman breed has disease resistance, overall hardiness and an outstanding maternal instinct The Angus breed is known for its superior carcass qualities, high fertility characteristics and high milking ability The

Brangus breed has proven resistant to heat and high humidity, but it also produces enough hair for adequate protection to cold climates. The cows are good mothers and the calves are usually of medium size at birth. These cattle have responded well to conditions of abundant feed but, also exhibit hardiness under stressful conditions as well (OSU, 1999a). For these reasons, productivity data for Brangus cattle were used.

The weaning weights and weaning rates were used to find the pounds of steer and heifer calf that the native and introduced cow would produce (Appendix Table A.5.). Reynolds, et al. and Magna and Segura reported weaning weights for steer calves. These weaning weights were adjusted for heifers by using 96 percent of the steer weaning weight (Walker, Lusby, and McMurphy). Although the weaning weights do not take into consideration the replacement heifers that will be kept for the herd, the pounds of heifer produced by each cow was adjusted to allow the herd to retain 10 heifers for every 100 cows produced.

In the model it is necessary to determine the cost of maintaining each cow one year The cost of the cow includes the cost of labor, veterinarian bills, supplemental feed, vehicle maintenance, fuel, depreciation and any other unexpected variable cost Due to a lack of detailed enterprise budgets that would report production costs, it was necessary to estimate these costs. It was difficult to estimate one average cost for the maintenance of these cows across each production region Some budgets were available for the arid region (Organizacion De Las Naciones Unidas Para La Agricultura Y La Alimentacion). Although these budgets varied dramatically from one to the other, it was determined that these costs were not unreasonable An approximate cost of $75 per cow on *ejido* land and $80 per cow on private land was estimated for the arid region. For the temperate region, it is assumed that these costs are approximately the same, $78 per cow on *ejido* land and $83 per cow on private land. Although commercial production is less specialized toward U.S. exports in this region, there is a greater portion of the dual purpose cows in this region. So this production is thought to increase costs slightly. The tropical region has more problems with pests and disease resistance so it is assumed that the cost per cow is higher in this region. Cost is estimated to be $85 per cow on *ejido* land and $90 per cow on private land. These estimates are based on the overall data that are available about these regions of production Latter it will be noted that the model exhibits little sensitivity to changes in these costs.

Finishing Activities

When calves reach weaning weights the model is allowed the option of sending those animals to feeding activities within the region or it can also send those calves elsewhere to be fed. The model can opt to send the calves to other regions in the model for fattening or it may export the calves to the United States. The mode of transportation for the movement of these calves is assumed to be truck. The transportation cost for moving these calves throughout Mexico is assumed to be a constant rate per mile. The transportation mileage between the three regions is then defined as movement between three major cities: Chihuahua, Mexico City and Villahermosa. The cost of exporting calves is calculated using the mileage from Chihuahua to the border-city of Ciudad Juarez. Therefore the cost per calf is based on the distance that the calf travels assuming that the truck is used to full capacity (Appendix Table A.8)

If weaned calves are kept in Mexico to be fed then they are either fed to finishing weight on pasture or they are sent to feedlots for finishing. Grass fattening is a very common practice in Mexico. This type of herd management is often called an extensive management system (Appendix Table A.4.). Often calves are put on grass after weaning as stockers until they reach slaughter weight. Slaughter weight for these calves is typically lighter than that of feedlot finished calves. The model is used to determine whether the introduced calf should finish on grass or on grain. This is done by sending the calves to either a feedlot activity or to a stocker activity. It is assumed that all native calves are moved after weaning to a stocker activity because there is a lack of data to indicate that these kinds of cattle are ever sent to feedlots. Since there were no data to support feedlot production of native cattle, this activity was omitted from the model.

For the linear programming model it was necessary to determine the cost of producing these calves whether they are fed extensively or intensively. Costs include the cost of labor, veterinarian bills, animal health supplies, supplemental feed, vehicle maintenance, fuel, depreciation and other variable costs. Those calves that are finished on grass are assumed to have fewer expenses than those calves finished in confined feeding operations. All calves that are kept on grass are assumed to have the same variable cost across all regions. Forty-five dollars per calf accounts for all costs except the costs of forage. All calves that are sent to the feedlot for finishing are assumed to have equal variable costs across all regions. These variable costs are estimated to be $55 per head for all costs except cost of feed. Due to a lack of information concerning this aspect of production, it is assumed that variable costs are relatively equal across regions of production. There is little sensitivity to these costs in the model.

To determine stocking rates for the cattle on pasture, it is necessary to consider the time element involved in feeding stocker calves. This model captures the Mexican cattle industry in a one-year time frame. During this time a cow needs one animal unit year of feed to maintain and provide nourishment for her calf. While a calf will likely spend anywhere from two to three years on pasture before it is able to reach finishing weight. There is a significant difference in the time a calf spends on forage between the three regions of production. In the arid/semiarid region calves generally spend 36 months on pasture, while in the temperate region they take 33 months and only 25.5 months in the tropical region (U.S. Meat Export Federation, et al.). It is necessary to adjust the stocking rates to reflect this time element in the model. In the model the number of animal units per hectare is established with forage balance equations. Stocking rates for the calves were determined by finding the metabolic weight of the calves and then calculating the conversion rate that would indicate the number animal units that each calf needs for that year. This is an estimate of the animal units of forage required per hectare per year for each calf To account for the time element, this number was multiplied by the number of years a calf generally spends in the pasture Table 3.4 presents the actual animal unit requirements of each calf for a year and for the total time period that a calf must stay on grass to reach finishing weight

Table 3.4. Animal Unit Requirements for Stocker Calves by Region

	Introduced Calves		Native Calves	
	Steers 950 lbs	Heifers 900 lbs	Steers 950 lbs	Heifers 900 lbs
Arid Region				
Stocking Rate in AUY	0.744694	0.717218	0.732664	0.705456
AUs per Calf Required	2.234082	2.151654	2.197991	2.116367
Temperate Region				
Stocking Rate in AUY	0.744694	0.717218	0.732664	0.705456
AUs per Calf Required	2.047908	1.97235	2.014825	1.940003
Tropical Region				
Stocking Rate in AUY	0.744694	0.717218	0.732664	0.705456
AUs per Calf Required	1.582475	1.524089	1.55691	1.499093

Although the animal units of forage required are different for steers and heifers, the model assumes that both steers and heifers will be fed for the same amount of time. Heifers finish at a lighter weight than steers because although heifers are kept on the same land as steers, they do not gain weight as fast as steers. Therefore, it is appropriate to assume a lighter finishing weight for the heifers (National Academy of Sciences).

The model has the option of sending introduced calves to the feedlot for finishing. Calves managed intensively will finish in approximately five to six months at approximately the same weight as the grass-fed calves and they will produce a different quality of beef The feedlot industry in Mexico is different from the industry in the U.S in the type of grains that are used and the amount of grain that is in the rations. Many feedlots in Mexico use grain sorghum as their primary energy source, while feedlots in the U.S. use primarily corn. This difference is important because corn has a 10 percent higher grain nutritional performance value than grain sorghum. These differences in productivity are reflected in the model by using more pounds of feed per pound of gain for the calves on sorghum than for the calves on corn In Mexican feedlots, grain accounts for 68.5 percent of the ration on average, while in the U.S., grain accounts for 82.5 percent of the ration (Arce-Diaz). This difference in the content of the rations also illustrates how Mexican feedlots could possibly be more productive. In the model, the feedlots will use only 68.5 percent grain in their rations. This is to replicate the current industry and its current practices. With the gradual installation of the free trade agreement, more feedlots may have access to corn through the U.S. grain markets.

The model is allowed to choose the grain that it will feed in the feedlot operations. It is assumed that grain is imported from the U.S. for this production activity. So grain is assumed to be one price and differentiated only by an assumed transportation cost. Prior to additional transportation costs, the price of corn is $108 per ton, sorghum is $135 per ton and other ingredients are $50 per ton (Arce-Diaz). These prices increase incrementally according to the region in which they are shipped. It is assumed that the feedlots in Mexico that feed corn would be managed very similarly to those that feed sorghum. Table 3.5 illustrates the requirements of feeder calves when being fed to a finishing weight in a confined feeding operation.

Table 3.5. Nutrient Requirements for Calves in Confined Feeding Operations

	Corn Fed Calves		Sorghum Fed Calves	
Feed Requirements	Steers	Heifers	Steers	Heifers
Pounds of Feed/Pound of Gain	6.8	7.85	7.6	8.85
Pounds of Total Gain	550	550	550	550
Pounds of Feed in Total	3740	4317.5	4180	4867.5
Ratio of Grain in Ration	0.685	0.685	0.685	0.685
Grain per Fed Calf in U.S. Tons	1.280	1.478	1.431	1.667
Other Feedstuff per Fed Calf in Tons	0.589	0.68	0.658	0.766

Slaughter Activities

When the calves are at their finishing weight, is assumed that they are to be slaughtered. These animals can be transported to another region of the country for slaughter or they can be slaughtered in the region where they were produced. The transportation of these finished animals is calculated in the same way as the transport of the weaned calves. Although transportation cost per animal is higher due to their larger weight and the fact that a smaller quantity of animals can be transported on the truck, the cost per mile for the truck remains the same (Appendix Table A.8.)

In the model the number of heifers produced by each cow is adjusted to account for keeping at least ten replacement heifers in an average herd size of 100. So it is assumed that for every 100 cows 10 will be culled. This translates to mean that each cow produces 1/10 of a culled cow in terms of slaughter animals. Therefore each cow produced generates 42 or 52 pounds of beef for native and introduced cows, respectively The model assumes that these cows are sent to municipal slaughterhouses due to the nature of the process.

Table 3.6. Meat Produced from Cow Culling

Improved Cows		Native Cows	
Cow Weight (lbs)	1100	Cow Weight (lbs)	900
Dressing %+Variety Meat %	47.34	Dressing %+Variety Meat %	47.34
Carcass Weight	520.78	Carcass Weight	426.09
W/Ten Cows Culled a Year	52.08	W/Ten Cows Culled a Year	42.61

Source: USDA-Market News, August 1999

Finished calves are slaughtered in either Municipal or TIF slaughter facilities throughout Mexico. The majority of slaughter activity in Mexico occurs in Municipal packing plants (SAGAR). TIF plants are more technically efficient than Municipality-owned plants. The average Municipal plant is smaller than the TIF facility in terms of the capacity of animals that can be processed per day. While Municipal plants process 120-150 head per day, TIF plants are capable of slaughtering up to 180 head per day (U.S. Meat Export Federation, et al.). The advantages of slaughter at the TIF plants are strict sanitary controls, more humanitarian slaughter practices, and the availability of cold storage and transportation (SAGAR). Slaughter in these plants has expanded slowly because the cost of slaughter in TIF plants is 30-50 percent higher than the cost in Municipal plants. It is assumed that the cost of slaughter for these two types of facilities is the same across Mexico, $17 per head for the TIF plants and $8 per head in the Municipal plants (U.S. Meat Export Federation, et al.). Currently only 20 percent of beef products processed in Mexico are processed in TIF facilities (SAGAR). To reflect the current situation in Mexico only 20 percent of the total beef demand was processed in TIF plants in the model. The remaining 80 percent was processed by municipal packing plants (SAGAR). It is assumed that all processing other than that occurring in TIF facilities will happen in municipal facilities. For the purposes of this research, Municipal plants are assumed to be all those slaughterhouses that are not federally inspected, not just those slaughterhouses that are owned by the state

Table 3.7. Percentage Distribution of Cattle Slaughtered in Mexico

	1990	1991	1992	1993	1994	1995	1996	1997
TIF Slaughter	13.2	10.7	13.5	16.6	16.1	18.8	20.4	19.4
Municipal Slaughter	55.6	53.1	49.4	51.1	47.6	49.5	50.3	49.5
In-Situ*	31.2	36.2	37.1	32.3	36.3	31.7	29.3	31.1

Source: SAGAR.

* Only the main state-owned slaughterhouses were included; all the rest were considered in-situ

Transportation of Beef

The model was not allowed to transport the beef products that were processed in these municipal plants due to their lack of refrigeration and the infrastructure of the market in which they sell their products (U.S. Meat Export Federation, et al.). Meat processed in TIF plants was transported between regions and was also exported to other countries. The same three cities for transporting live animals were used to calculate the cost of transporting meat between regions. The cost for importing beef products from the U.S was also calculated by assuming that all imports enter at the border-city of *Ciudad Juarez*. The cost of transportation is calculated as a cost per pound to best fit the units of the model although it is assumed that beef will be transported by metric tons.

Table 3.8. Transportation Cost for Beef Products

Meat Transportation	\$/MT Mile[1]	Mileage[2]	\$/MT[1]	\$/pound
Domestic Transport				
Chihuahua-Federal District	0.06	931	54.09	0.02534
Chihuahua-Villahermosa	0.06	1440	83.66	0.03919
Federal District-Chihuahua	0.06	931	54.09	0.02534
Federal District-Villahermosa	0.06	509	29.57	0.01385
Villahermosa-Chihuahua	0.06	1440	83.66	0.03919
Villahermosa-Federal District	0.06	509	29.57	0.01385
Import Transport				
Ciudad Juarez-Chihuahua	0.06	247	14.35	0.00672
Ciudad Juarez-Federal District	0.06	1180	68.55	0.03211
Ciudad Juarez-Villahermosa	0.06	1689	98.12	0.04597

Source: [1] USDA, 1999a. [2] Noble.

Beef Production

Beef production in this model is divided into two separate quality levels. What the model designates as "Fed Beef" is beef that originated from those animals fed grain rations in an intensive management system or a feedlot production system. The beef that is called

"Non-Fed Beef" is beef that comes from those animals that have been managed extensively on grass to reach their finishing weight. Beef obtained from intensively managed operations is considered a high quality product and is designated as marbled. While beef obtained from extensive operations is considered lean and very tender (U.S Meat Export Federation, et al.). Beef imported from the U.S. is considered "fed beef" unless it is a variety meat product. Due to the inferior quality of variety meats, these meats are considered to be a portion of the "non-fed beef" in this model. So when variety meats are imported or obtained through processing they are categorized as non-fed beef in the model. All slaughtered calves produce a certain percentage of variety meats that will be considered non-fed beef in the model. The percentage of variety meats obtained from each animal slaughtered was calculated using national statistics provided by the USDA (Appendix Table A.9.). Variety meats comprise an important part of import from the United States. To determine the prices of variety meats per pound and the price of beef muscle cuts per pound the following data were used

Table 3.9. Value of Imports from U.S. for 1997

	Value	Volume (MT)	Volume (lbs)	Price/Pound
Beef	$299,845,000	106,517	234,827,378	$1.28
Variety Meats	$45,233,000	39,444	86,958,242	$0.52

Source: U.S. Department of Commerce, 1999a. and U.S. Department of Commerce, 1999b.

The model is also allowed to export beef products produced in TIF slaughterhouses. Either fed beef or non-fed beef products can be exported from all three regions of production. There are port cities in all three regions so that the transportation costs are assumed to be minimal in each region. The cost of exports is estimated by dividing the export value for beef products, $12,978,000, by the number of pounds exported in 1997 (12,334,737). By this calculation the objective function value for these beef exports is $1.05 per pound (FAO). These data do not allow for the differentiation in price between fed and non-fed beef exports.

Consumption

To determine the regional consumption for Mexico, it was necessary to calculate the current population per region. The most recent census was conducted in 1990 (Pick and Butler). Therefore, it was necessary to inflate this population by 20.56 percent, which was the growth rate for the national population from 1990 to 1997 (SAGAR). State population totals were aggregated to the regional totals The same three regions were used for consumption as for production This method of calculating the population assumes that there was no migration between the three regions in this time period

To accurately reflect the current consumption, it was necessary to determine the per capita consumption of fed beef and non-fed beef. To determine the per capita consumption of fed beef the sum of fed beef imported from the U.S. and fed beef produced in Mexico was divided by the total population.

Table 3.10. Fed Beef Consumption

US Beef Exports to Mexico[1]	106,517	MT
Mexico Fed Beef Production[2]	161,559	MT
Total Fed Beef Consumed	268,076	MT
Converted to Pounds	591,000,314	pounds
Population in 1997[3]	95,522,266	
Fed Beef Consumption per capita	6.187	lbs/person/year

Sources: [1]U.S. Department of Commerce, 1999a. [2]Gonzalez-Padilla [3]SAGAR.

To determine the per capita consumption of non-fed beef, the sum of domestically produced non-fed beef, imported non-fed beef, and imported variety meats derives the total non-fed beef consumed nationally. This total divided by the total population derives the per capita consumption of 39.83 pounds per person per year. This total was then adjusted for the portion of beef that the dairy sector contributes that is not accounted for in the model. There are approximately 2,000,000 head of dairy cows in Mexico (USDA, 1999b.). Estimating that ten percent of this herd is culled every year, each cow in the herd would contribute approximately 52 pounds of beef, which accounts for approximately 1.09 pounds of dairy cow beef consumed per capita. Therefore, the adjusted non-fed beef consumption per capita was 38 7434 pounds per person annually.

Table 3.11. Non-Fed Beef Consumption

Domestic Production less Fed Beef Produced[1]	1,638,441	MT
Imports from other countries[1]	48,039	MT
Variety Meats Imported from US[2]	39,444	MT
Total Non-Fed Beef	1,725,924	MT
Converted to Pounds	3,804,972,086	pounds
Population in 1997[3]	95,522,266	
Total Non-Fed Beef Consumption	39.833	lbs/person/year
Adjusted Non-Fed Beef Consumption	38.74	lbs/person/year

Source: [1] USDA, 1999b. [2] U.S. Department of Commerce, 1999b. [3] SAGAR.

In Table 3.12 the total beef demand was determined by calculating each region's annual consumption for the two types of beef This was determined by multiplying the per capita consumption of beef for each person by the population of each region The temperate region clearly has the largest demand for beef. Two of the most populated cities, Mexico City and Guadalajara, are located in this region. Although this method does not allow income distribution or taste and preferences to influence the consumption in each region, it does account for all beef consumption in Mexico. If the model were influenced by other factors the beef consumption might vary slightly per region but the overall results of this method are thought to be accurate with current trends in Mexico.

Table 3.12. Consumption of Beef by Region

Regions	Fed-Beef (lbs)	Non-Fed Beef (lbs)
Arid/Semiarid	135,711,002	849,831,201
Temperate	316,654,413	1,982,910,712
Tropical	138,630,845	868,115,449
National Total	590,996,260	3,700,857,362

Procedures

Mathematical programming is a method of determining a profit maximizing or cost minimizing combination of activities that is feasible with respect to a set of linear resource constraints. This form of mathematical programming provides a means for allocating scarce resources to competing activities The basic assumptions about the nature of the production process, the resources and activities are implicit in the linear programming model (Hazell and Norton). To better understand the Mexican cattle industry and the resources that are essential to this industry, a mathematical programming model was constructed

There are a number of assumptions about the nature of the production process, its resources, and activities that are implicit to the linear programming model (Hazell and Norton). These assumptions are:

1. Optimization. It is assumed that an appropriate objective function is either maximized or minimized
2. Fixedness. At least one constraint has a nonzero right hand side coefficient

3. Finiteness. It is assumed that there are only a finite number of activities and constraints to be considered so that a solution may be sought.
4. Determinism. All coefficients in the model are assumed to be known constants.
5. Continuity. It is assumed that resources can be used and activities produced in quantities that are fractional units.
6. Homogeneity. It is assumed that all units of the same resource or activity are identical.
7. Additivity The activities are assumed to be additive in the sense that when two or more are used, their total product is the sum of their individual products. No interaction between activities is permitted
8. Proportionality. The gross margin and resource requirements per unit of activity are assumed to be constant regardless of the level of the activity used.

The assumptions of additivity and proportionality together define the linearity of the activities and giving justification to the name linear programming. These assumptions are stringent and must hold for all rows and columns in the model, but these assumptions may not hold for the agricultural production process. The model may be constructed with flexibility without violating these assumptions (Hazell and Norton)

The industry is modeled as two separate production steps, the first being the cattle production process and the second being the beef production process. Figure 3.1 illustrates the different steps of the calf production process in Mexico (U.S. Meat Export Federation, et al). It is important to understand how the forage on each type of land can be used and that stocker calves compete with the cows for forage on both private and *ejido* land. Figure 3.2. shows the commercialization steps that are necessary to produce beef in Mexico (U.S. Meat Export Federation, et al.). This is an accurate picture of the two separate slaughter sectors in Mexico and how the beef products produced by each have very different paths to the individual consumers.

Figure 3.1 Cattle Production Process

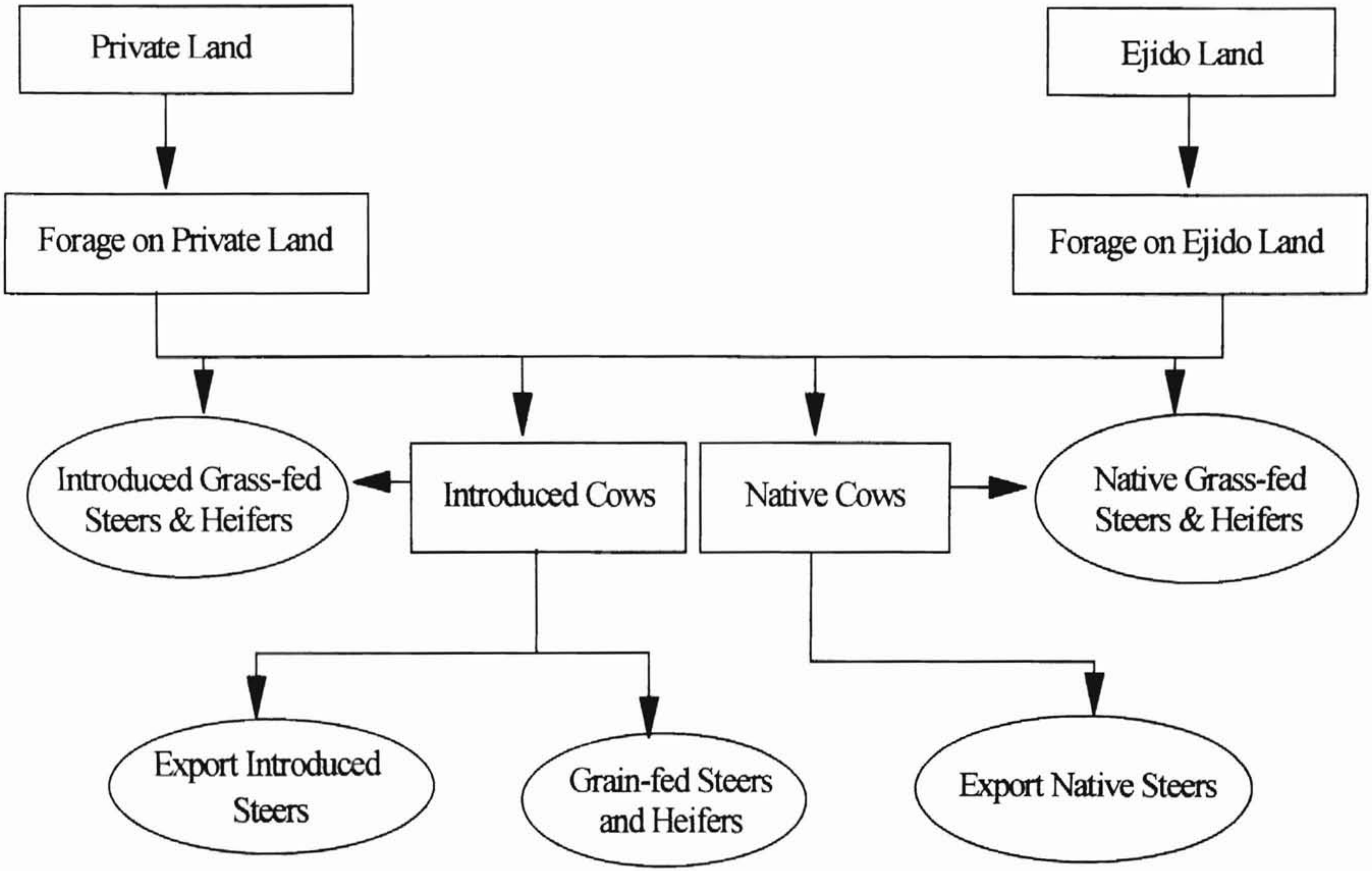
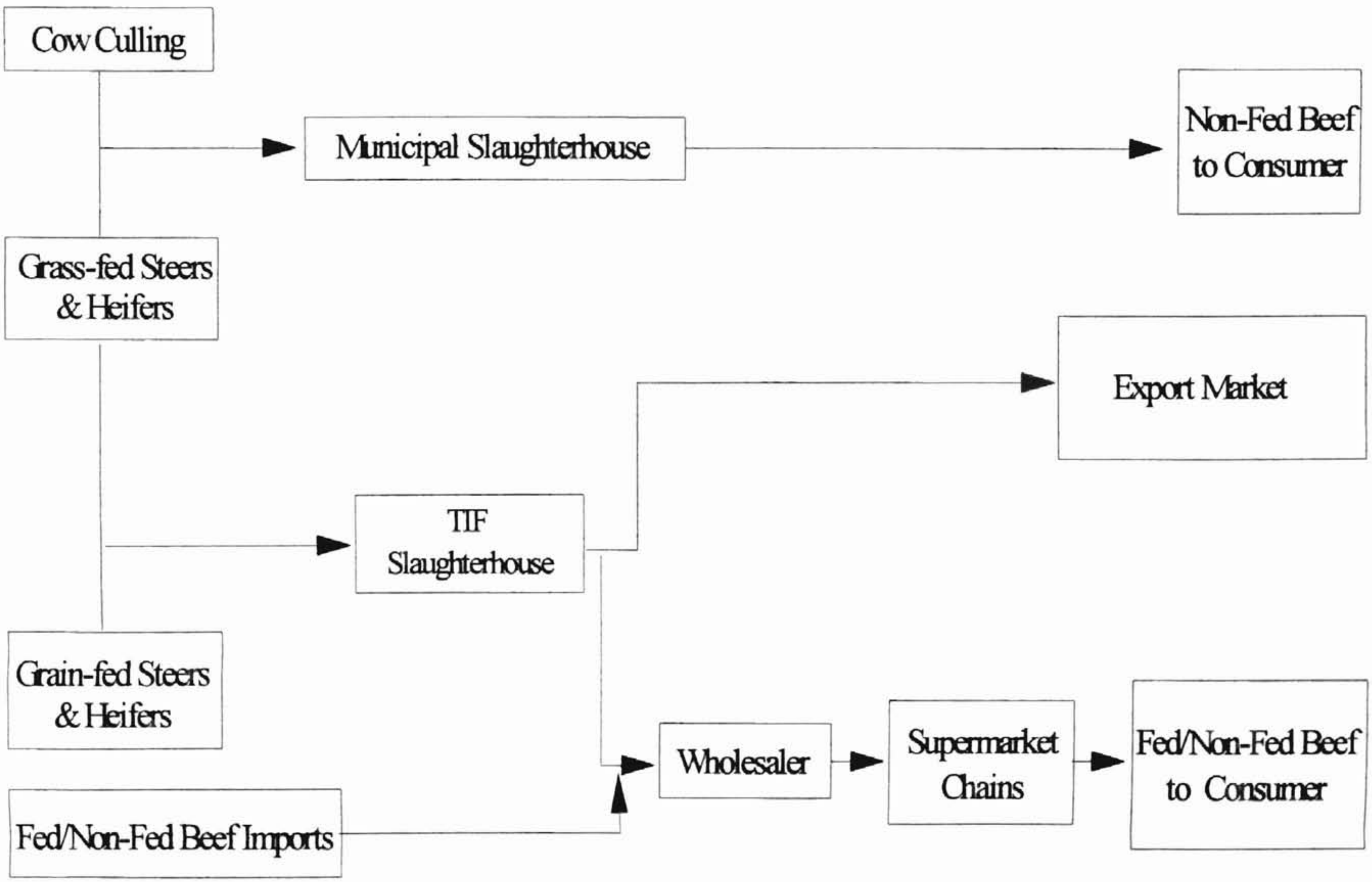


Figure 3.2 Beef Production Process



In this mathematical programming model the objective function is such that the model will minimize the cost of providing Mexican consumers with a pre-specified level of beef for consumption. The model includes five types of activities such as production, slaughter, transportation, import and export activities. The objective function is:

$$(3.1)\quad \textit{Minimize } Z = \sum_{j}\sum_{r}\sum_{q}\sum_{d} X_{jrqd} C_{jrqd} + \sum_{j}\sum_{r}\sum_{g} XX_{jrg} CC_{jrg} + \sum_{j}\sum_{r}\sum_{q}\sum_{g}\sum_{d} XXX_{jrqgd} CCC_{jrqgd} + \sum_{k}\sum_{r}\sum_{m}\sum_{s} S_{krms} CS_{krms} + \sum_{l}\sum_{r}\sum_{q}\sum_{g} T_{lrqg} CT_{lrqg} + \sum_{l}\sum_{r}\sum_{m} TT_{lrm} CTT_{lrm} + \sum_{p}\sum_{r}\sum_{m} I_{prm} CI_{prm} + \sum_{b}\sum_{r} Q_{br} CQ_{br} - \sum_{x}\sum_{q} E_{xq} P_{xq} - \sum_{x}\sum_{r}\sum_{m} EE_{xrm} PP_{xrm}$$

for $j = 1, \ldots,$ n production activities
$r = 1, \ldots, 3$ regions
$q = 1, \ldots, 2$ live animal types
$d = 1, \ldots, 2$ land types
$g = 1, \ldots, 2$ genders of animal
$k = 1, \ldots,$ v slaughter activities
$m = 1, \ldots, 2$ meat products
$s = 1, \ldots, 2$ slaughter facilities
$l = 1, \ldots,$ u transportation activities
$p = 1, \ldots,$ w import activities
$b = 1, \ldots, 2$ grain type
$x = 1, \ldots,$ h export activities

In this equation the following variables are represented so that: Z is the value to be minimized; X_{jrqd} is the level of production activity j in region r of animal type q on land type d; C_{jrqd} is the cost of production activity j in region r of animal type q on land type d; XX_{jrg} is the level of grain fed steer production activity j in region r of animal gender g; CC_{jrg} is the cost of production activity j in region r of animal gender g; XXX_{jrqgd} is the level of grass fed steer production activity j in region r of animal type q of animal gender g on land type d; CCC_{jrqgd} is the cost of grass fed steer production activity j in region r of animal type q of animal gender g on land type d; S_{krms} is the level of slaughter activity k in region r producing product m in slaughter facility s; CS_{krms} is the cost of slaughter activity k in region r producing product m in slaughter facility s; T_{lrqg} is the level of transportation activity l in region r of animal type q and gender g; CT_{lrqg} is the cost of transportation activity l in region r of animal type q and gender g; TT_{lrm} is the level of transportation activity l in region r of product m; CTT_{lrm} is the cost of transportation activity l in region r for product m; I_{prm} is the level of import activity p to region r for product m; CI_{prm} is the cost of import activity p to region r of product m; Q_{br} is the level of grain type b for region r; CQ_{br} is the cost of grain type b for region r; E_{xq} is the level of export activity x of animal type q; P_{xq} is the revenue of export activity x of animal quality q; EE_{xrm} is the level of export activity x from region r of product m; PP_{xrm} is the revenue of export activity x from region r of product m.

This equation is to be optimized subject to the following resource constraints. The first constraint states that the land resources used by the model must be less than or equal to the land resources available in each of the production regions. This constraint is defined as:

(3.2)
$$\sum_{j} A_{jrd} X_{jrd} \leq B_{rd}$$

for all $r = 1, \ldots, 3$ regions
$d = 1, \ldots, 2$ land types

where X_{jrd} is the solution value for activity j in region r for land type d, A_{jrd} is the land required per unit of activity j in region r for land type d; and B_{rd} is the land available for use in region r and land type d.

The following equations are balance equations used to balance the use and production of resources throughout the model. The forage constraints limit forage consumption to be less than or equal to forage production

$$(3.3) \qquad \sum_j \sum_q AA_{jrqd} X_{jrqd} + \sum_j \sum_q \sum_g AAA_{jrqgd} XXX_{jrqgd} - \sum_j \sum_q AAAA_{jrqd} X_{jrqd} \leq 0$$

for all $r = 1, \ldots, 3$ regions
$d = 1, \ldots, 2$ land types

where X_{jrqd} is the level of production activity j in region r of animal type q on land type d; AA_{jrqd} is the level of animal units required per unit of activity j in region r according to animal type q and land type d; XXX_{jrqgd} is the level of grass fed animal production activity j in region r of animal type q of gender g on land type d; AAA_{jrqgd} is the level of animal units required per unit of activity j in region r according to animal type q and gender g on land type d; X_{jrqd} is the level of animal units required per unit of activity j in region r according to animal type q on land type d; $AAAA_{jrqd}$ is the level of animal units produced per unit of activity j in region r according to animal type q on land type d

The next constraint ensures that the pounds of calf produced are balanced with the pounds of calf used in further production.

$$(3.4) \qquad \sum_j \sum_g F_{jrg} XX_{jrg} + \sum_j \sum_q \sum_g FF_{jrqg} XXX_{jrqg} + \sum_l \sum_q \sum_g FFF_{lrqg} T_{lrqg}$$
$$\sum_j \sum_q \sum_g FFFF_{jrqg} X_{jrqg} \leq 0$$

for all $r = 1, \ldots, 3$ regions
$d = 1, \ldots, 2$ land types

where XX_{jrg} is the level of grain fed animal activity j in region r of gender g; F_{jrg} is the level of pounds required per unit of activity j in region r of gender g; XXX_{jrqg} is the level of grass fed animal activity j in region r of animal type q and gender g; FF_{jrqg} is the level of pounds required per unit of activity j in region r of animal type q and gender g; T_{lrqg} is the level of transportation activity l in region r for animal type q and gender g; FFF_{lrqg} is the level of pounds required per unit of activity l in region r of animal type q and gender

g; X_{jrqg} is the level of cow activity j in region r of animal type q and gender g; $FFFF_{jrqg}$ is the level of pounds of calf produced by activity j in region r of animal type q and gender g.

This constraint balances the level of grain purchased with the level of grain used in the model.

(3.5)
$$\sum_j \sum_g H_{jrgb} XX_{jrgb} - Q_{br} \leq 0$$

for all $r = 1, \ldots, 3$ regions
$b = 1, \ldots, 2$ grain types

where XX_{jrgb} is the level of grain fed animal activity j in region r for gender g and grain b; H_{jrgb} is the level of grain required per unit of activity j in region r for gender g and grain b; Q_{br} is the level of the grain purchasing activity b in region r

The next constraint equates the level of grain fed animals slaughtered with the level of fattened calves produced.

(3.6)
$$\sum_k L_{krg} XXS_{krg} + \sum_l T_{lrg} LA_{lrg} - \sum_j W_{jrg} XX_{jrg} \leq 0$$

for all $r = 1, \ldots, 3$ regions
$g = 1, \ldots, 2$ genders

where XXS_{krg} is the level of slaughter activity k in region r of gender g; L_{krg} is the level of pounds of calf used by slaughter activity k in region r of gender g; T_{lrg} is the level of transportation activity l in region r of gender g; LA_{lrg} is the level of pounds of calf used and produced by transportation activity l in region r of gender g; XX_{jrg} is the level of grain fed calf activity j in region r of gender g; W_{jrg} is the level of pounds of calf produced by activity j in region r of gender g

This constraint equates the quantity of grass fed animals slaughtered with the level of grass fed animals produced.

$$(3.7) \qquad \sum_{k} LL_{krg} XXS_{krg} + \sum_{l} LAL_{lrg} T_{lrg} - \sum_{j} WW_{jrg} XXX_{jrg} \leq 0$$

for all $r = 1, \ldots, 3$ regions
$g = 1, \ldots, 2$ genders

where XXS_{krg} is the level of slaughter activity k in region r of gender g; LL_{krg} is the level of pounds of calf used by slaughter activity k in region r of gender g; T_{lrg} is the level of transportation activity l in region r of gender g; LAL_{lrg} is the level of pounds of calf used and produced by transportation activity l in region r of gender g; XXX_{jrg} is the level of grass fed calf activity j in region r of gender g; WW_{jrg} is the level of pounds of calf produced by activity j in region r of gender g.

Limitations were put on the quantity of variety meats that were available for importation to Mexico. Due to the nature of the model if left unconstrained the model would choose to import as much variety meat as possible to meet all non-fed beef demand. Due to the nature of the production of variety meats it is not feasible to import that great a proportion of variety meats.

$$(3.8) \qquad \sum_{p} \sum_{r} I_{pr} \leq 86,974,000$$

where I_{pr} is the level of import activity p in region r

The optimal level of beef production is also subject to the level of beef demanded by the consumers in Mexico. The following constraint states that the level of beef demanded in each region must be met by either the quantity of beef produced from slaughter, by the level of beef transported from other regions or by beef imported from the United States. This equation must also consider the ability of Mexico to export beef to other countries. Demands are designated according to the different types of meat products produced and the facilities that they are produced in. The demand constraint for fed beef produced in TIF facilities is as follows:

$$(3.9) \qquad \sum_k \sum_g BBB_{krg} S_{krg} \sum_p I_{pr} - \sum_x EE_{xr} + \sum_l TT_{lr} \geq D_r$$

$$r = 1, \ldots, 3 \text{ regions}$$

where S_{krg} is the level of slaughter activity k in region r for gender g; BBB_{krg} is the level of fed beef produced by slaughter activity k in region r for gender g; I_{pr} is the level of fed beef import activity p in region r; EE_{xr} is the level of fed beef export activity x in region r; TT_{lr} is the level of fed beef transportation activity l in region r; and D_r is the level of fed beef demand in region r. The demand constraint for non-fed beef produced in TIF facilities is:

$$(3.10) \qquad \sum_k \sum_g B_{krg} S_{krg} + \sum_k \sum_g BB_{krg} SS_{krg} + \sum_p I_{pr} - \sum_x EE_{xr} + \sum_l TT_{lr} \geq DD_r$$

$$\text{for all } r = 1, \ldots, 3 \text{ regions}$$

where S_{krg} is the level of slaughter activity k in region r for gender g; B_{krg} is the level of nonfed beef (variety meats) produced by each unit of slaughter activity k in region r for gender g; SS_{krg} is the level of slaughter activity k in region r for gender g; BB_{krg} is the level of non-fed beef produced by each unit of slaughter activity k in region r for gender g; I_{pr} is the level of non-fed beef import activity p in region r; EE_{xr} is the level of non-fed beef export activity x in region r; TT_{lr} is the level of non-fed beef transportation activity l in region r; and DD_r is the level of non-fed beef demand for TIF facilities in region r. The next constraint represents the demand for non-fed beef products processed in Municipal facilities:

(3.11) $$\sum_{k}\sum_{g} BBBB_{krg} X_{jrq} + \sum_{k}\sum_{g} BB_{krg} SS_{krg} \geq DDD_r$$

for all $r = 1, \ldots, 3$ regions

where X_{jrq} is the level of cow production j in region r of animal type q, $BBBB_{krq}$ is the level of non-fed beef produced by each unit of slaughter activity k in region r of animal type q; SS_{krg} is the level of slaughter activity k in region r for gender g; BB_{krg} is the level of non-fed beef produced by each unit of slaughter activity k in region r for gender g; DDD_r is the level of non-fed demand for Municipal in region r.

Due to the nature of the linear programming model an additional constraint was added to ensure the production of cows in the temperate and tropical regions. The model found that it was optimal to produce cows in the arid/semiarid region and stocker calves in the tropical region. Therefore, it was producing all cows in the arid/semiarid region and transporting all their calves to the tropical region. To better represent the number of subsistence farmers, it was necessary to stipulate that the model produce native cows on *ejido* land in the temperate and tropical regions. This economic model has been built to imitate the costs and benefits of the Mexican cattle industry. Due to the nature of subsistence farming often production on *ejido* land is not responsive to market signals and therefore it is necessary to force the model to account for this production. To determine this constraint, the number of native cows that could be supported on the *ejido* land in the tropical region while this land was also supporting the calf crop of those cows was determined. The same procedure was used to determine the number of native cows needed in the temperate region.

(3.11) $$X_2 \geq 862{,}696$$

(3.12) $$X_3 \geq 2{,}996{,}619$$

where X_2 is the minimum level of cows that can be produced in the temperate region; and X_3 is the minimum level of cows that can be produced in the tropical region. Through this process it was determined that in the tropical region at least 2,996,619 native cows must be produced on *ejido* land while in the temperate region at least 862,696 native cows must be produced on *ejido* land.

CHAPTER IV

RESULTS

The Benchmark Model

The focus of this research has been in building a linear programming model of the Mexican cattle market. To evaluate the accuracy of the model, a series of checks and balances were used for validation to determine if the model appropriately represents the Mexican cattle industry. The model does not precisely represent all intricacies of the production system, but it should present an accurate picture for the aggregate market

The results of the benchmark model present an overall accurate picture of the aggregated Mexican cattle market Many of the production trends that exist in the market are apparent in the model. Table 4.1 lists the results of the model in terms of the forage used for cattle production and the number of cattle produced in Mexico as a whole as well as per region

Table 4.1. Forage and Cattle Production according to the Benchmark Model

Region	Available Forage hectares	Forage in Use hectares	Cow Production head	Exportation of Steers to U.S. head	Feedlot Production head	Grass-Fed Production head
Arid/Semiarid	60,310,387	60,310,387	9,615,168	525,608	987,462	1,043,143
Temperate	18,583,426	18,583,426	862,696	0	0	1,631,929
Tropical	22,595,443	22,595,443	2,996,619	0	0	3,300,404
Total	101,489,255	101,489,255	13,474,483	525,608	987,462	5,975,477

The model allocates all of the available land to forage production whether it is *ejido* or private. This illustrates that the resources of Mexico are being used in full to produce forage for cattle production. The model reflects a greater number of cows than what was produced according to the 1991 census. There were 9,839,859 beef and dual purpose cows in 1991. By this measure, the model overproduces approximately 3 million cows. But since the 1991 census many changes have occurred that may have effected the inventory of cows in the country. The distribution of cows across production regions is reasonable. In accordance with the census data, the arid region produces the majority of cows, while the tropical region still produces a portion of the inventory and the temperate region produces very few. This distribution can be explained by the strong dairy production that occurs in the temperate and tropical regions as well as the use of tropical forests for the finishing of stocker calves.

The benchmark model solution exports 525,608 steers to the United States, while feeding 987,462 calves in feedlots and 5,975,477 calves on pasture throughout Mexico. These results reflect the overall trends of the Mexican cattle industry. In 1997, 667,000 head of cattle were exported to the United States. This number decreased during 1998 and 1999 due to lower calving rates and drought conditions in the country.

(USDA,1999b.). Exporting half a million steers is very reasonable. In the model the exportation of steers relies heavily on the ability of Mexico to meet its domestic demand for beef products.

The best available data indicate that 600,000 calves were fed in Mexican feedlots in 1996 (Gonzalez-Padilla). Given changes in trade policy between the U.S. and Mexico this is most likely a growing industry. An increase of 300,000 head is not unreasonable. The model allocates 5,939,997 head of stocker calves to be fed to finishing weight on pasture. This is approximately 75.7 percent of the calves produced in Mexico. It is assumed that the estimate is also reasonable.

When all of the steer and heifer calf activities are aggregated, total calf production is estimated to be 7,488,548 head. This can be compared to the 1998 calf crop of 8,400,000 head produced (USDA, 1999b.). The USDA also accounts for the dairy calves produced. If it is assumed that dairy cows have at least a 50 percent calving rate, then the number of beef or dual purpose calves is approximately 7,300,000 head.

In Table 4.2 the results of the model are presented in terms of the amount of beef produced and the origin of that beef. Beef can either be produced in TIF or Municipal slaughter facilities or imported from the United States. In the model, TIF facilities are allowed to process either fed or non-fed beef, while municipal facilities only process non-fed beef. All beef produced from cow culling is processed in the municipal facilities. All variety meats, whether harvested in Mexican facilities or imported, are considered non-fed beef.

Table 4.2. Beef Production and Imports for Mexican Consumption

Region	TIF Meat Production pounds	Municipal Meat Production pounds	Carcass Meat Imports pounds	Variety Meat Imports pounds	TIF Meat Exports pounds
Arid/Semiarid	932,985,737	679,864,961	0	86,974,020	0
Temperate	0	1,586,328,569	0	0	0
Tropical	311,207,976	694,492,359	0	0	0
Total	1,244,193,712	2,960,685,890	0	86,974,020	0

The fixed point demands are defined in the model so that 20 percent of the beef demand is processed in TIF slaughter facilities or imported from the U.S. and 80 percent of the nation's beef demand is processed in municipal facilities. Based on the model, the majority of TIF production occurs in the northern region. The existing feedlot industry is in the northern region and all of those cattle are sent to TIF facilities. The temperate region does not process beef in TIF facilities. As of 1998 TIF facilities in the temperate region processed less than 100,000 head of cattle (SAGAR). Much of this is due to the fact that there are large municipal plants that are state owned in Mexico City and Guadalajara. For this same reason the quantity of beef produced in municipal facilities is also reasonable. The amount of beef produced by the TIF and municipal facilities in the model seems to follow the trends of the country and is consistent with published data.

Variety meats are the only beef products that the model imports to aid in meeting domestic demand. In reality more of the carcass meats are actually imported from the U.S. than the model reflects. There are a couple of possible explanations for this understatement in the model. The first is that the model does not reflect the demand of the tourist and restaurant industry in the country. This industry imports much of its beef products from the U.S. to satisfy the demands of American travelers. Another possibility is that the quality and cut of Mexican fed beef and U.S. fed beef are assumed to be the same. There may be a niche market for U.S. beef products that is not represented in the model. Due to the strain on the Mexican production system to meet domestic demands, Mexico does not export any fed or non-fed beef products.

In Table 4.3 the results are presented in terms of the quantity of fed and non-fed beef produced in the different types of facilities per region. All beef produced from cow culling is processed in the municipal plant in the same region that the cow is produced. The model does not permit the transport of cows to other regions for slaughter. Also, the model does not allow the transport of beef products from municipal slaughter facilities to other regions for consumption. Beef products slaughtered in municipal facilities are not transported to other regions.

Table 4.3. Quantity of Beef Produced in TIF and Municipal Slaughter Facilities

Regions	TIF Fed Beef pounds	TIF Non-Fed Beef pounds	Municipal Non-Fed Beef pounds	Municipal Non-Fed Beef from Cows pounds
Arid/Semiarid	590,996,260	341,989,477	179,126,224	500,738,737
Temperate	0	0	1,549,569,720	36,758,849
Tropical	0	311,207,976	566,808,603	127,683,756
Total	590,996,260	653,197,452	2,295,504,547	665,181,342

In total the model indicates 4,204,879,602 pounds of beef are produced for consumption. The model has the option of producing or importing the stipulated amount of beef from the United States. In this situation the model produces 98 percent of the beef that is required for the domestic demands, while 2 percent of the beef demanded is imported as variety meat products. The USDA reported that Mexico produced 3,968,280,000 pounds of beef for consumption in 1997 (USDA, 1999b.). The difference between actual and baseline estimates of beef production is 236,599,602 pounds. When including the variety meat imports, a total of 4,291,853,622 pounds of beef is needed to satisfy the fixed point demands used in the model. This compares to Mexico's total consumption for 1997 of 4,395,972,400 pounds according to the USDA. So while these initial results suggest that the model is over producing beef products, in total the model is actually slightly under producing the quantity of beef needed for Mexico. Although the legitimacy of the total beef production of the model can be documented as being reasonable, there are little data to determine the current production of fed and non-fed beef products in the two different types of slaughter facilities.

Table 4.4 depicts the results of the model in terms of the number of cows produced in each region on each type of land. These results illustrate that the number of introduced cows produced is approximately 71.4 percent of the total herd. While the number of native cows is 28.6 percent of the total herd. Cow production is also divided across production regions. According to these results, the majority of cows are located in the arid/semiarid region, and all of the introduced cows produced by the model are produced in this region. While the tropical region produces almost three million native cows, and the temperate region produces less than one million native cows.

Table 4.4. Cow Production by Type and Land Tenure

Region	Introduced Cows head	Native Cows head	Total Cows head
Arid/Semiarid	9,615,168	0	9,615,168
On *Ejido*	3,548,110	0	3,548,110
On Private	6,067,059	0	6,067,059
Temperate	0	862,696	862,696
On *Ejido*	0	862,696	862,696
On Private	0	0	0
Tropical	0	2,996,619	2,996,619
On *Ejido*	0	2,996,619	2,996,619
On Private	0	0	0
Total	9,615,168	3,859,315	13,474,483
On *Ejido*	3,548,110	3,859,315	7,407,425
On Private	6,067,059	0	6,067,059

These results show that it is economically optimal for cow production to be concentrated in the arid/semiarid region. Furthermore, the production of introduced cows is optimal in the northern region The quantity of native cows produced on *ejido* lands are restricted exogenous of the model. The model is forced to produce cows in the temperate and tropical regions of the model. Since grazing calves was found to be more profitable in the temperate and tropical regions, the model attempted to put all stocker production in these two regions. It was necessary to require an adequate level of cow production in the temperate and tropical regions to better represent the subsistence farming of the *ejidatarios*.

Table 4.5 contains the results of the model according to the system in which these calves are finished in each region for each land tenure system According to these results 52.6 percent of the introduced calves are finished on grazing lands in the tropical region and 62 percent of the native calves are finished on land in the tropics. The temperate region finishes the other 38 percent of the native calves on its private and *ejido* lands. The arid/semiarid region finishes 24.4 percent of the introduced calves with all of them on private land. The arid/semiarid region is also home to the 987,462 calves that are put in confined feeding operations to be fattened. These confined feeding operations require about 1.8 million tons of grain for their operation.

Table 4.5. Total Calf Production and Grain Use

Regions	Grass-Fat Production head of Introduced	Grass-Fat Production head of Native	Grain-Fed Production head	Grain Used U.S. Tons
Arid/Semiarid	1,043,143	0	987,462	1,846,555
Private	1,043,143	0		
Ejido	0	0		
Temperate	980,241	651,689	0	0
Private	980,241	106,729		
Ejido	0	544,960		
Tropical	2,245,964	1,054,441	0	0
Private	2,245,964	0		
Ejido	0	1,054,441		
Total	4,269,348	1,706,129	987,462	1,846,555

The model shows that it is optimal to finish the majority of the calves in the two southern production regions of the country. This is logical due to the large number of cows located in the arid/semiarid production region. There are no data available that would indicate the quantity of cattle finished in each region. Due to the climatic conditions in the arid/semiarid region it would make sense that grass feeding is minimal in this region. The temperate and tropical regions offer more forage per acre in general across the regions. In 1996, less than 600,000 animals were fed in feedlots throughout

Mexico (Gonzalez-Padilla). The majority of the feedlot industry is located in the arid/semiarid region due to its close proximity to the U.S. and better access to American grain (Arce-Diaz). It is possible that the feedlot industry in northern Mexico has grown and is now finishing nearly one million head

Table 4.6 summarizes the transportation of live animals between the regions of production. This table includes the transportation of calves before and after they have been fed to a finishing weight. The trend for transportation is that the stocker/feeder calves move from the arid/semiarid (R1) region toward the temperate (R2) and then on to the tropical (R3) region. The only transportation for fed steers and heifers is their movement to the temperate region from the tropical region to help satisfy the demand for beef. This is in part due to the large number of calves fed in the tropical region and in part due to the large portion of the population located in the temperate region.

Table 4.6. Transportation of Live Animals between Regions

Type of Livestock	From R1 to R2[a]	From R2 to R1[a]	From R1 to R3[a]	From R3 to R1[a]	From R2 to R3[a]	From R3 to R2[a]
Steers(400#)-Introduced	1,188,861	0	0	0	1,065,341	0
Heifers (384#)-Introduced	2,037,343	0	0	0	1,180,623	0
Steers (371#)-Native	0	0	0	0	0	297,034
Heifers (356#)-Native	0	0	0	0	0	0
Feedlot Steers	0	0	0	0	0	0
Feedlot Heifers	0	0	0	0	0	0
Grass-fed Introduced Steers	0	0	0	0	0	979,767
Grass-fed Introduced Heifers	0	0	0	0	0	0
Grass-fed Native Steers	0	0	0	0	0	0
Grass-fed Native Heifers	0	0	0	0	0	525,907

[a] R1=Arid/Semiarid Region, R2=Temperate Region, R3=Tropical Region.

Table 4.7 summarizes the transportation of beef produced in TIF facilities from one region to another region. Since all of the fed beef is produced in the arid/semiarid region there is transportation from that region to the other two regions. This is so that the fed beef demands in the temperate and tropical regions are met. It is not necessary to operate TIF plants in all regions of the country Non-fed beef travels from the arid and the tropical regions into the temperate regions to aid in meeting the fixed point demands of the highly populated temperate region. Overall almost 20 percent of the beef produced in Mexico is transported to a different region. The fed beef transportation represents about eleven percent of the beef produced and is transported because the TIF plant only processes grain-fed cattle in the region in which they were produced.

Table 4.7. Transportation of Beef by Quality Level

Regional Transportation	TIF Fed Beef pounds	TIF Non-Fed Beef pounds
From R1 to R2	316,654,413	258,997,257
From R2 to R1	0	0
From R1 to R3	138,630,845	0
From R3 to R1	0	0
From R2 to R3	0	0
From R3 to R2	0	137,584,886
Total Beef Transported	455,285,258	396,582,142

Comparative Statics

In the second part of this chapter, the model will be used to estimate the impact of specific changes in the Mexican cattle and beef industry. This will aid in demonstrating some of the capabilities of the model and for what purposes the model can be used. There are many possibilities for growth and change in the Mexican beef industry. Some of the possibilities that will be explored are growth in the demand for beef products and changes in the productivity of Mexico's production practices.

Increase in Beef Demand.

In the first scenario the model will evaluate an overall increase in the quantity of beef demanded for both fed and non-fed beef products. For the purposes of this scenario, overall demand for beef products was estimated to increase by seven percent. This means that the increase in the quantity demanded was reflected in both the fed and non-fed beef markets. This change would be likely given an overall increase in income for the Mexican consumers. The model indicates many changes in the Mexican beef cattle industry. The model no longer produces any calves for exportation or to be put in confined feeding operations. All calves are fed on grass to satisfy the demand for non-fed beef in the country, while fed beef demand is met through importing beef cuts from the United States. Cow production in Mexico decreased by nine percent due to the reallocation of land to pasture finishing activities and production of fewer calves for export and confined feeding. The model produced 12 percent less calves even though the demand for beef increased. This may seem contradictory that the model produces fewer calves even though demand has increased, but in effect the model must choose a more expensive alternative to satisfy the increase in the demand for beef. The model is limited in that it must produce a certain level of non-fed beef for the population because imports of these types of beef products are restricted. Although a small portion of this beef can be imported as variety meat imports from the U.S., this activity is constrained in the model to a realistic amount. Therefore, the model chooses to place all calves on grass for fattening and import the more expensive fed beef products from the United States. In this situation Mexico's beef industry actually produces eight percent less beef than before the increase in demand. As a result of the increase in demand Mexico would import almost 16 percent of the total beef consumed in the country, where before these imports accounted for only two percent of the total beef consumption of Mexico. One of the most notable consequences of this increase in the quantity of beef demanded is that the cost of beef produced by Mexico per pound increases from $.67 to $.93 which is a 38 percent increase in the cost of production.

Increase in Fed Beef Demand

For this analysis the mathematical programming model evaluated a 100% increase in the demand for fed beef products while the consumption of all beef products per person remains constant. Therefore, reducing the quantity of non-fed beef demanded. In essence this allows for six additional pounds of fed beef to be substituted for non-fed beef keeping per capita consumption constant At this point it also becomes optimal for Mexico to produce beef for export Mexico produces 290,005,989 pounds of fed beef for export, which is approximately 6.5 percent of their total beef production. According to the available data the TIF plants that are currently operating could potentially process approximately 1.73 billion pounds of beef per year (SAGAR). Although the model only exports 290 million pounds the total production in TIF facilities as indicated by the model is 2.007 billion pounds. To process this quantity of beef in the TIF facilities would mean that Mexico would have to build other TIF plants with the ability to process at least 277 million pounds of beef.

Cow production is almost fifteen percent higher than in the benchmark model. Logically with the extra cow production there are significant increases in the exportation of steers and the placement of calves in confined feeding operations Given the changes in consumption, Mexico would feed over 2.4 million head of calves in confined feedlots To support the expansion in the feedlot industry, 4.8 million tons of grain would be needed Although Mexico could produce this many steers to be fed in feedlots, it is questionable as to whether or not their feedlot industry is developed enough to handle this large herd According to the available data, in 1996 their feedlot industry only fed 600,000 head (Gonzalez-Padilla) To feed 2.4 million head the current feedlot system must expand to feed four times its current capacity. In the short run this would not be feasible and Mexico would be unable to export while possibly turning to the United States for their fed beef supply. While total calf production increases by sixteen percent, there is a significant decline in the quantity of grass-fed calves. The decrease in the demand for non-fed beef frees up resources and makes it feasible to exceed demands. Although the demand for fed beef essentially doubled for the Mexican consumer, the price of all beef produced in Mexico fell by seventeen percent. The cost of beef produced per pound declined from $.67 to $.51 per pound

Implications of an Increase in Beef Demand and an Increase in Fed Beef Demand.

These two comparative statics demonstrate the capabilities of the Mexican beef industry in terms of meeting the demands for fed and non-fed beef. The first comparative static demonstrates that an increase in the overall demand for beef puts a great strain on the Mexican beef production system. Any further increases in demand would cause Mexico to turn to sources outside its borders for a portion of its beef supply. Currently any increase in overall demand mainly affects the non-fed beef production since this is approximately 84 percent of the Mexicans' per capita consumption To meet the seven-percent increase in the quantity demanded, all production except non-fed beef production was suspended so that the country could satisfy its non-fed beef demands. This indicates that any further increases in the quantity of beef demand will not be feasible by their system of production. This would indicate that the consumers would then need to eat a greater portion of fed beef or import non-fed beef from another country If Mexican consumers were to increase their demand for fed beef then based on the model, Mexico could satisfy that demand by producing greater quantities of fed beef. An alternative possibility is that Mexico opts to import non-fed beef from countries such as Australia, Argentina and Brazil. Due to the similar production systems in these countries their beef products would be similar to non-fed beef production in Mexico. These comparative statics illustrate that Mexico's future beef production is heavily dependent on changes in the consumers' demand concerning the quantity and quality of beef products desired. In essence these changes will depend not only on income and population growth but also on the consumers tastes and preferences.

An Increase in Cow Productivity

This scenario considers a general increase in the level of productivity by improving the productivity of those cows owned by private landowners. This improvement was accomplished by increasing the pounds of steer and heifer produced by each cow by ten percent. This scenario was used to illustrate the significance of an increase in cow productivity for Mexico's cattle industry. It is assumed that this increase in productivity was accomplished through improved management styles and did not require the use of additional capital or resources. These comparative statics illustrate some obvious changes when there is an improvement in cow productivity. One obvious change is the decrease in the cost of production of beef per pound. Cost per pound was reduced by 8 percent from \$.67 to \$.62 per pound. Improving cow productivity would prove to be beneficial to consumers in this way. Another obvious change is that the exportation of steers almost doubles due to this change. Although grass-fed and grain-fed steer production differs very little, the exportation of steers doubles allowing Mexico to export over one million head of steers. Other changes that occurred were a shift in introduced cow production from the *ejido* lands to the private lands. Although there was not a significant increase in cow production, introduced cow production by private landowners in the arid/semiarid region increased by 40 percent while production of those same cows decreased likewise on *ejido* lands. At the same time grass-fat production of introduced steers in the arid/semiarid region shifted from private to *ejido* owned land in order to compensate for the increase in private land use for cows.

An Increase in Cow Productivity while Increasing the Demand for Beef

The fourth comparison evaluates the results of the effect of an increase in cow productivity as well as an increase in the quantity of beef necessary to satisfy consumer demands. This simulation will estimate the change in cattle and beef production given an increase in cow productivity on privately owned land and a seven- percent increase in the quantity of beef products demanded. This scenario will illustrate the response of the beef cattle industry when productivity is improved and then when the quantity of beef demanded increases. After the cow productivity has been increased and then the level of beef required has also increased, the production system reacts much like it did in the first scenario The model reallocates resources to meet the strenuous demands for non-fed beef products. There is an eleven- percent reduction in the number of cows produced when the quantity of beef demanded increases by seven percent Due to the overwhelming demand for non-fed beef all calves that are produced in the country are kept and fed on pasture. Only six percent of the calves produced are put into confined feeding operations for fed beef production and the grain needed for these operations declines by almost 50 percent. The majority of the fed beef demand for the country is met by importing over 369 million pounds of beef from the United States. Another notable consequence of this increase in demand is the increase in the cost of beef production. The cost of producing beef increases from $.62 to $.82 per pound which is more than a 31 percent increase. This will have a significant affect on consumers.

The Implications of an Increase in Cow Productivity and a Subsequent Increase in Beef Demand

These two scenarios illustrate the capabilities of the Mexican production system in meeting its own demands for beef products given changes in the productivity of their cow herd. After evaluating the subsequent increase in the quantity of beef demanded, it is obvious that an improvement in the productivity of the cow herd would be beneficial to not only producers but also to consumers. Although an increase in the productivity of the cow herd will have positive effects overall, it is obvious that this increase in productivity is not enough by itself to relieve all the stress put on the Mexican production system when demands for non-fed beef increase. While the model is able to meet the increased demands, it still must suspend all export activities and eliminate the majority of feedlot production activities. These comparisons illustrate that increases in productivity may aid Mexico in meeting its domestic demands for beef but their production system is still going to be strained given the nature of their production.

Table 4.8. Benchmark and Comparative Statics Results

	Benchmark	+ 7% Beef		+100% Fed Beef		+10% Weaning		+10% Weaning & +7% Beef	
Resource Allocation	Level	Level	% Change	Level	% Change	Level	% Change	Level	% Change
Land Use	101,489,255	101,489,255	0.00	101,489,255	0.00	101,489,255	0.00	101,489,255	0.00
Arid/Semiarid	60,310,387	60,310,387	0.00	60,310,387	0.00	60,310,387	0.00	60,310,387	0.00
Temperate	18,583,426	18,583,426	0.00	18,583,426	0.00	18,583,426	0.00	18,583,426	0.00
Tropical	22,595,443	22,595,443	0.00	22,595,443	0.00	22,595,443	0.00	22,595,443	0.00
Cows Production	13,474,483	12,281,159	-8.86	16,129,884	19.71	13,465,020	-0.07	11,970,908	-11.16
Arid/Semiarid	9,615,168	8,421,844	-12.41	10,970,010	14.09	9,605,705	-0.10	8,111,593	-15.64
Temperate	862,696	862,696	0.00	862,696	0.00	862,696	0.00	862,696	0.00
Tropical	2,996,619	2,996,619	0.00	4,297,179	43.40	2,996,619	0.00	2,996,619	0.00
Calf Production	7,488,548	6,627,765	-11.49	9,096,215	21.47	7,986,022	6.64	7,072,139	-5.56
Grass Fed Calves	5,975,477	6,627,765	10.92	4,529,541	-24.20	5,987,364	0.20	6,625,615	10.88
Arid/Semiarid	1,043,143	1,636,512	56.88	439,138	-57.90	1,050,299	0.69	1,728,358	65.69
Temperate	1,631,929	1,692,721	3.73	1,620,789	-0.68	1,636,661	0.29	1,600,320	-1.94
Tropical	3,300,404	3,298,533	-0.06	2,469,615	-25.17	3,300,404	0.00	3,296,937	-0.11
Grain Fed Calves	987,462	0	N/A	2,470,674	150.20	987,462	0.00	446,524	-54.78
Arid/Semiarid	987,462	0	N/A	2,470,674	150.20	987,462	0.00	446,524	-54.78
Temperate	0	0	N/A	0	N/A	0	N/A	0	N/A
Tropical	0	0	N/A	0	N/A	0	N/A	0	N/A
Grain Used (U.S. Tons)	1,846,555	0	N/A	4,812,080	160.60	1,846,555	0.00	963,933	-47.80
Steer Exports	525,608	0	N/A	2,096,000	298.78	1,011,195	92.39	0	N/A
Fed Beef Produced	590,996,260	0	N/A	1,471,998,509	149.07	590,996,260	0.00	262,743,380	-55.54
Arid/Semiarid	590,996,260	0	N/A	1,471,998,509	149.07	590,996,260	0.00	262,743,380	-55.54
Temperate	0	0	N/A	0	N/A	0	N/A	0	N/A
Tropical	0	0	N/A	0	N/A	0	N/A	0	N/A
Non-Fed Beef Produced	3,613,883,342	3,880,231,706	7.37	3,022,887,082	-16.35	3,613,883,342	0.00	3,880,231,706	7.37
Arid/Semiarid	1,021,854,438	1,241,757,430	21.52	788,197,842	-22.87	1,022,877,192	0.10	1,249,142,904	22.24
Temperate	1,586,328,569	1,700,495,633	7.20	1,333,005,039	-15.97	1,586,328,569	0.00	1,700,495,633	7.20
Tropical	1,005,700,335	937,978,643	-6.73	901,684,201	-10.34	1,004,677,581	-0.10	930,593,169	-7.47
Total Beef Produced	4,204,879,602	3,880,231,706	-7.72	4,494,885,591	6.90	4,204,879,602	0.00	4,142,975,086	-1.47
Non-Fed Beef Imports	86,974,020	86,974,020	0.00	86,974,020	0.00	86,974,020	0.00	86,974,020	0.00
Fed Beef Imports	0	632,365,998	N/A	0	N/A	0	N/A	369,622,618	N/A
Beef Exported	0	0	N/A	290,005,989	N/A	0	N/A	0	N/A
Total Beef Consumed	4,291,853,622	4,599,571,724	7.17	4,291,853,622	0.00	4,291,853,622	0.00	4,599,571,724	7.17

CHAPTER V

CONCLUSION

Summary

A unique relationship has developed between the United States and Mexico in terms of beef and cattle trade in the last ten years Higher feeder cattle prices have prompted the exportation of feeder cattle to the U.S. from Mexico. While an increase in the demand for beef in Mexico has prompted a large increase in the importation of red meat from the United States In 1997 Mexico exported approximately 667,000 head of cattle to the United States of which nearly all were feeder cattle (USDA, 1999b.) In turn Mexico has become the second largest importer of U.S. beef products Since the late 1980s, red meat exports to Mexico have expanded from 22,000 metric tons in 1987 to 154,582 metric tons in 1998 (Peel) and (USDA, 1999b.). Mexico has struggled to produce the beef that their consumers demand Mexico produced approximately 1.8 million metric tons of beef in 1997 with a total herd of 26.9 million head (USDA, 1999b.) While in comparison the United States produced over 11.7 million metric tons of beef with a total herd of 101 million head in 1997 (FAO)

The development and implementation of a free trade agreement among the North American countries has altered the future of agriculture among these countries. In the past the U.S. has dominated Canada and Mexico in terms of production of a majority of agricultural products, this could soon change in many areas of agriculture. These three countries have played unique roles in the history of the cattle industry. With the United States leading the way and Canada following close behind, Mexico has struggled to compete in terms of the quantity and quality of beef cattle that they are able to produce. The focus of this research has been in building a model that replicates the Mexican cattle industry with respect to its production system, its resource base, and its technology base.

This research will determine the expected change in the population of beef cattle in Mexico, given the available resources and free trade flows between the United States and Mexico. This study will take into account the quantity and quality of forage and genetic resources available in Mexico and how they are used to produce cattle. After determining how the cattle population could change given changes in demand and productivity of the cow herd, it will be possible to predict how other aspects of the industry will be effected. This will allow a more accurate analysis of the future evolution of the Mexican industry By evaluating the allocation of resources to Mexico's cattle industry and analyzing Mexico's production system, the estimations for actual growth in Mexico's industry will be more accurate. By accurately depicting the outlook for Mexico's production system, U.S producers can be better prepared for further changes in the cattle industry

Summary of Results

The linear programming model that was produced accurately reflected the majority of the trends existing in the Mexican beef cattle market When examining the impact of increases in demand for beef products, it was obvious that Mexico will struggle to continue to meet the demand for non-fed beef products due to their resource limitations. Any increases in fed beef demand can be met by either developing confined feeder operations or by importing these products from the United States depending on the level of non-fed beef produced. This would indicate that while demand for non-fed beef products is high in Mexico, they would continue to import beef products from the United States. This is due to a limited resource base that allows the production of only enough calves to sustain the necessary level of non-fed beef demand If the demand for non-fed beef increases by more than ten percent of its current level than Mexico will be forced to import non-fed beef from another source.

The model also examines the changes that occur when the productivity of the cow herd improves and then the demand for beef products increases. The model estimates that increases in the productivity of the private cow herds will benefit consumers in the long run by reducing the cost of beef production This improvement in cow productivity also allows for the production of steers for export to the United States. When the demand for beef products is increased by seven percent, the model still struggles to produce the amount of non-fed beef demanded by the model The cost of beef production increases by 31 percent and Mexico begins importing U.S. beef again to fulfill their fed beef demands.

These results would imply that any increases in the demand for non-fed beef would continue to strain the cattle production system that exists in Mexico. Due to the nature of the production of grass fed beef and the natural resources required, production of grass fed beef cattle cannot expand drastically beyond current levels. Simply the time required for the growth and fattening of a calf in this type of production system is very costly in terms of the resources required. It is obvious that the future of the Mexican cattle industry will be determined by the demand of the Mexican consumers in terms of their demand for fed or non-fed beef products.

Limitations of Research

There are limitations to modeling the Mexican beef cattle industry using the math programming method. One of these limitations is in the nature of the linear programming model. Linear programming allows the analysis of a production system given one point in time. This limits the evolution of the model as separate events occur over time. Linear programming models are somewhat limiting because they are very prone to "all or nothing" solutions. This means that if the model determines an optimal production activity it will channel all resources into that activity. This problem is addressed in this model by using constraints to limit the production of some activities to be of a reasonable level

Another limitation is in the amount and availability of information concerning forage and stocking rates in Mexico. Very little information is available concerning the quantity and type of forage available for cattle to graze in the different production regions of Mexico. Many sources say that pastureland in Mexico has been overgrazed and mismanaged so that its condition will affect cattle production for many years, but no further research into this issue was available for the purposes of this research. For this research, stocking density estimates were computed based upon the best available data

This is an area of the model that could be improved given better information about the quantity and quality of range resources in Mexico

There was limited availability to costs of production for cattle production units in Mexico. This information was available for some of the northern region but not for the temperate and tropical regions Although there are differences in the costs of production according to each region, costs of production also vary within the region. To adjust the model for this problem the costs of production for all activities were relative across all regions. It should also be noted that optimal levels of production for the regions are fairly insensitive to small changes in the costs of production

Recommendations for Future Research

With the implementation of NAFTA, Mexico, Canada, and the U.S. have new opportunities to establish unique trade relationships with each other. As this happens it is imperative that the U.S. agricultural industries have adequate information about agricultural production in Canada and Mexico Future research into the agricultural production in Mexico and the trends behind that production would serve the U.S. agricultural sectors well More specifically there is very little information about the pasture and forage base in Mexico in terms of quality or quantity. These data are very important in determining the most economical use for the land in Mexico. Further research concerning the demands of the Mexican consumers for beef products in the future would be beneficial to U.S. producers and processing companies. This would enable these entities to develop products that are better suited for the Mexican consumer.

But for a complete demand analysis of the Mexican consumers, it is necessary to weigh very heavily the culture and traditions of the Mexican people.

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APPENDIX

Table A.1. Inventory and Bulls or Cows as per Function or Animal Production and Milk Production by Region and Land Tenure

Region	Total Inventory (hd)	Bulls (hd)	Bulls (%)	Cows (hd)	Cows (%)	Only Milk Prod Cows (hd)	Only Milk Prod Cows % Cow Herd	Only Meat Prod Cows (hd)	Only Meat Prod Cows % Cow Herd	Dual Purpose Cows (hd)	Dual Purpose Cows % Cow Herd
United States of Mexico	12,586,246	824,125	6.55	11,762,121	93.45	1,922,262	16.34	5,190,591	44.13	4,649,268	39.53
URBAN	167,565	10,580	6.31	156,985	93.69	51,638	32.89	34,875	22.22	70,472	44.89
RURAL	12,418,681	813,545	6.55	11.605,136	93.45	1,870,624	16.12	5,155,716	44.43	4,578,796	39.45
Only Private	6,732,316	439,096	6.52	6,293,220	93.48	980.335	15.58	3,238,636	51.46	2,074,249	32.96
Only *Ejidal*	5,153,985	340,289	6.60	4,813,696	93.40	807.610	16.78	1,723,393	35.80	2,282,693	47.42
Mixed	532,380	34,160	6.42	498,220	93.58	82,679	16.59	193,687	38.88	221,854	44.53
ARID REGION	4,984,021	304,746	6.11	4,679,275	93.89	600,943	12.84	2,669,705	57.05	1,408,627	30.10
URBAN	44,717	2,464	5.51	42,253	94.49	10,387	24.58	14,944	35.37	16,922	40.05
RURAL	4,939,304	302,282	6.12	4,637,022	93.88	590,556	12.74	2,654,761	57.25	1,391,705	30.01
Only Private	3,132,669	200,809	6.41	2,931,860	93.59	343,125	11.70	1,909,421	65.13	679,314	23.17
Only *Ejidal*	1,609,158	89,906	5.59	1,519,252	94.41	225,225	14.82	651,020	42.85	643,007	42.32
Mixed	197,477	11,567	5.86	185,910	94.14	22,206	11.94	94,320	50.73	69,384	37.32
TEMPERATE REGION	3,243,361	226,038	6.97	3,017,323	93.03	697.972	23.13	895,775	29.69	1,423,576	47.18
URBAN	91,997	5,723	6.22	86,274	93.78	33,994	39.40	12,604	14.61	39,676	45.99
RURAL	3,151,364	220,315	6.99	2,931,049	93.01	663,978	22.65	883,171	30.13	1,383,900	47.22
Only Private	1,517,082	104,611	6.90	1,412,471	93.10	358,370	25.37	434,128	30.74	619,973	43.89
Only *Ejidal*	1,472,815	103,823	7.05	1,368,992	92.95	273,073	19.95	404,265	29.53	691,654	50.52
Mixed	161,467	11,881	7.36	149,586	92.64	32,535	21.75	44,778	29.93	72,273	48.32
TROPICAL REGION	4,358,864	293,341	6.73	4,065,523	93.27	623,347	15.33	1,625,111	39.97	1,817,065	44.69
URBAN	30,851	2,393	7.76	28,458	92.24	7,257	25.50	7,327	25.75	13,874	48.75
RURAL	4,328,013	290,948	6.72	4,037,065	93.28	616,090	15.26	1,617,784	40.07	1,803,191	44.67
Only Private	2,082,565	133,676	6.42	1,948,889	93.58	278,840	14.31	895,087	45.93	774,962	39.76
Only *Ejidal*	2,072,012	146,560	7.07	1,925,452	92.93	309,312	16.06	668,108	34.70	948,032	49.24
Mixed	173,436	10,712	6.18	162,724	93.82	27,938	17.17	54,589	33.55	80,197	49.28

Source :INEGI.

Table A.2. Inventory of Cattle by Quality per Entity, Land Tenure, and Natural Pasture Availability

Region	Total (hd)	*Corrientes* (hd)	*Corrientes* (%)of herd	*Fino* (hd)	*Fino* (%) of herd	*De Cruza* (hd)	*De Cruza* (%) of herd
ESTADOS UNIDOS MEXICANOS	23,865,899	7,061,985	29.59	6,855,050	28.72	9,948,864	41.69
URBAN	277,147	82,669	29.83	105,781	38.17	88,697	32.00
RURAL	23,588,752	6,979,316	29.59	6,749,269	28.61	9,860,167	41.80
Without Natural Pasture	12,242,173	4,647,834	37.97	2,976,494	24.31	4,617,845	37.72
With Natural Pasture	11,346,579	2,331,482	20.55	3,772,775	33.25	5,242,322	46.20
Only Private	12,927,955	2,382,596	18.43	4,848,110	37.50	5,697,249	44.07
Without Natural Pasture	4,676,592	1,086,780	23.24	1,728,024	36.95	1,861,788	39.81
With Natural Pasture	8,251,363	1,295,816	15.70	3,120,086	37.81	3,835,461	46.48
Only *Ejidal*	9,632,341	4,268,849	44.32	1,653,694	17.17	3,709,798	38.51
Without Natural Pasture	7,030,725	3,354,727	47.72	1,124,135	15.99	2,551,863	36.30
With Natural Pasture	2,601,616	914,122	35.14	529,559	20.36	1,157,935	44.51
Mixed	1,028,456	327,871	31.88	247,465	24.06	453,120	44.06
Without Natural Pasture	534,856	206,327	38.58	124,335	23.25	204,194	38.18
With Natural Pasture	493,600	121,544	24.62	123,130	24.95	248,926	50.43
ARID REGION TOTALS	8,935,752	2,200,023	24.62	3,015,397	33.75	3,720,332	41.63
URBAN	75,359	25,974	34.47	22,190	29.45	27,195	36.09
RURAL	8,860,393	2,174,049	24.54	2,993,207	33.78	3,693,137	41.68
Without Natural Pasture	3,491,336	1,362,802	39.03	886,666	25.40	1,241,868	35.57
With Natural Pasture	5,369,057	811,247	15.11	2,106,541	39.23	2,451,269	45.66
Only Private	5,737,941	759,338	13.23	2,440,372	42.53	2,538,231	44.24
Without Natural Pasture	1,308,897	221,415	16.92	566,594	43.29	520,888	39.80
With Natural Pasture	4,429,044	537,923	12.15	1,873,778	42.31	2,017,343	45.55
Only *Ejidal*	2,764,434	1,305,467	47.22	462,847	16.74	996,120	36.03
Without Natural Pasture	2,033,160	1,081,080	53.17	286,321	14.08	665,759	32.75
With Natural Pasture	731,274	224,387	30.68	176,526	24.14	330,361	45.18
Mixed	358,018	109,244	30.51	89,988	25.14	158,786	44.35
Without Natural Pasture	149,279	60,307	40.40	33,751	22.61	55,221	36.99
With Natural Pasture	208,739	48,937	23.44	56,237	26.94	103,565	49.61

Table A.2. (Continued) Inventory of Cattle by Quality per Entity, Land Tenure, and Natural Pasture Availability

TEMPERATE REGION TOTALS	6,269,271	2,430,539	38.77	1,674,872	26.72	2,163,860	34.52
URBAN	147,017	37,637	25.60	68,123	46.34	41,257	28.06
RURAL	6,122,254	2,392,902	39.09	1,606,749	26.24	2,122,603	34.67
Without Natural Pasture	3,860,011	1,790,130	46.38	936,200	24.25	1,133,681	29.37
With Natural Pasture	2,262,243	602,772	26.64	670,549	29.64	988,922	43.71
Only Private	2,595,157	710,400	27.37	876,894	33.79	1,007,863	38.84
Without Natural Pasture	1,515,437	543,555	35.87	527,531	34.81	444,351	29.32
With Natural Pasture	1,594,441	365,248	22.91	537,475	33.71	691,718	43.38
Only *Ejidal*	2,794,898	1,341,850	48.01	555,575	19.88	897,473	32.11
Without Natural Pasture	2,308,070	1,222,842	52.98	414,212	17.95	671,016	29.07
With Natural Pasture	768,176	322,659	42.00	148,249	19.30	297,268	38.70
Mixed	326,414	135,774	41.60	75,965	23.27	114,675	35.13
Without Natural Pasture	218,238	101,498	46.51	50,309	23.05	66,431	30.44
With Natural Pasture	122,001	39,646	32.50	28,850	23.65	53,505	43.86
TROPICAL REGION TOTAL	8,660,876	2,431,423	28.07	2,164,781	24.99	4,064,672	46.93
URBAN	54,771	19,058	34.80	15,468	28.24	20,245	36.96
RURAL	8,606,105	2,412,365	28.03	2,149,313	24.97	4,044,427	46.99
Without Natural Pasture	4,890,826	1,494,902	30.57	1,153,628	23.59	2,242,296	45.85
With Natural Pasture	3,715,279	917,463	24.69	995,685	26.80	1,802,131	48.51
Only Private	4,258,948	781,140	18.34	1,411,909	33.15	2,065,899	48.51
Without Natural Pasture	2,013,047	387,455	19.25	686,139	34.08	939,453	46.67
With Natural Pasture	2,245,901	393,685	17.53	725,770	32.32	1,126,446	50.16
Only *Ejidal*	4,004,941	1,547,941	38.65	656,603	16.39	1,800,397	44.95
Without Natural Pasture	2,705,072	1,059,981	39.18	426,294	15.76	1,218,797	45.06
With Natural Pasture	1,299,869	487,960	37.54	230,309	17.72	581,600	44.74
Mixed	342,216	83,284	24.34	80,801	23.61	178,131	52.05
Without Natural Pasture	172,707	47,466	27.48	41,195	23.85	84,046	48.66
With Natural Pasture	169,509	35,818	21.13	39,606	23.37	94,085	55.50

Source: INEGI.

Table A.3. Units of Production and Inventory of Bovine Cattle per Land Tenure System and Farm Size

Name	Total Farms	Total (hd)	*Corrientes* Farms	*Corrientes* (hd)	*Fino* Farms	*Fino* (hd)	*De Cruza* Farms	*De Cruza* (hd)
ARID REGION TOTAL	300,044	8,935,752	171,761	2,200,023	57,400	3,015,397	99,556	3,720,332
URBAN	4,420	75,359	2,151	25,974	1,010	22,190	1680	27195
RURAL	295,624	8,860,393	169,610	2,174,049	56,390	2,993,207	97,876	3,693,137
Without Natural Pasture	205,753	3,491,336	132,681	1,362,802	33,153	886,666	58,063	1,241,868
With Natural Pasture	89,871	5,369,057	36,929	811,247	23,237	2,106,541	39,813	2,451,269
Less than 2 Ha.	12,845	179,774	7,391	69,560	2,236	36,991	4,460	73,223
More than 2 less than 5 Ha	11,034	178,304	5,861	62,600	2,021	36,514	4,230	79,190
More than 5 less than 20 Ha	19,438	408,453	9,083	115,402	4,193	120,302	8,093	172,749
More than 20 less than 50 Ha	10,533	318,202	4,500	76,627	2,478	91,214	4,705	150,361
More than 50 less than 100 Ha	8,258	337,879	3,041	71,651	2,163	106,063	3,993	160,165
More than 100 less than 1000 Ha.	20,159	1,577,346	5,869	238,782	6,556	572,553	10,384	766,011
More than 1000 less than 2500 Ha.	3,917	780,354	671	72,986	1,623	328,734	2,175	378,634
More than 2500 Ha.	3,687	1,588,745	513	103,639	1,967	814,170	1,773	670,936
Only Private	87,558	5,737,941	35,430	759,338	25,878	2,440,372	35,952	2.538,231
Without Natural Pasture	36,737	1,308,897	17,994	221,415	9,970	566,594	12,171	520,888
With Natural Pasture	50,821	4,429,044	17,436	537,923	15,908	1.873.778	23,781	2.017,343
Less than 2 Ha.	3,018	52,456	1,507	14,621	747	19.032	1,046	18,803
More than 2 less than 5 Ha	3,398	68,097	1,649	17,769	819	20,985	1,288	29,343
More than 5 less than 20 Ha	8,766	226,762	3,984	50.798	2,246	87,785	3,482	88,179
More than 20 less than 50 Ha	7,134	239,424	2,914	50.814	1,847	76,030	3,184	112,580
More than 50 less than 100 Ha	5.909	262,906	2,080	50,919	1,641	88,379	2,875	123,608
More than 100 less than 1000 Ha.	15,645	1,368,949	4,252	193,827	5,317	512,256	8,274	662,866
More than 1000 less than 2500 Ha.	3,547	724,642	608	66,351	1,449	305,071	1,997	353,220
More than 2500 Ha.	3,404	1,485,808	442	92,824	1,842	764,240	1,635	628,744
Only *Ejidal*	195,910	2,764,434	127,200	1,305,467	28,242	462,847	57,481	996,120
Without Natural Pasture	161,810	2,033,160	110,127	1,081,080	21,913	286,321	43,654	665,759
With Natural Pasture	34,100	731,274	17,073	224,387	6,329	176,526	13,827	330,361
Less than 2 Ha.	9,315	118,688	5,562	51,472	1,398	15,995	3,243	51,221
More than 2 less than 5 Ha	7,131	100,023	3,908	40,829	1,119	13,847	2,757	45,347
More than 5 less than 20 Ha	9,530	158,251	4,515	56,829	1,755	28,652	4,120	72,770
More than 20 less than 50 Ha	2,565	55,968	1,121	16,998	497	11,354	1,175	27,616
More than 50 less than 100 Ha	1,737	51,027	683	13,658	385	13,172	818	24,197
More than 100 less than 1000 Ha.	3,360	135,938	1,194	30,393	952	42,827	1,512	62,718

Table A.3. (Continued) Units of Production and Inventory of Bovine Cattle per Land Tenure System and Farm Size

More than 1000 less than 2500 Ha.	236	32,740	31	4,640	125	14,570	95	13,530
More than 2500 Ha.	214	78,639	59	9,568	93	36,109	100	32,962
Mixed	12,156	358,018	6,980	109,244	2,270	89,988	4,443	158,786
Without Natural Pasture	7,206	149,279	4,560	60,307	1,270	33,751	2,238	55,221
With Natural Pasture	4,950	208,739	2,420	48,937	1,000	56,237	2,205	103,565
Less than 2 Ha.	508	8,630	322	3,467	89	1,964	169	3,199
More than 2 less than 5 Ha	501	10,226	300	4,044	81	1,682	183	4,500
More than 5 less than 20 Ha	1,143	23,602	584	7,818	195	3,892	495	11,892
More than 20 less than 50 Ha	828	22,934	459	8,980	131	3,803	342	10,151
More than 50 less than 100 Ha	642	25,522	298	7,675	144	4,799	316	13,048
More than 100 less than 1000 Ha.	1,125	71,374	404	13,896	284	17,196	585	40,282
More than 1000 less than 2500 Ha.	119	22,846	27	1,996	43	9,260	73	11,590
More than 2500 Ha.	17,993	782,355	7,177	74,762	4,475	380,865	7,835	326,728
TEMPERATE REGION TOTAL	590,503	6,269,271	396,991	2,430,539	93,367	1,674,872	143,066	2,163,860
URBAN	9,305	147,017	4,231	37,637	2,620	68,123	3,262	41,257
RURAL	581,198	6,122,254	392,760	2,392,902	90,747	1,606,749	139,804	2,122,603
Without Natural Pasture	470,445	3,860,011	329,907	1,790,130	69,482	936,200	101,797	1,133,681
With Natural Pasture	110,753	2,262,243	62,853	602,772	21,265	670,549	38,007	988,922
Less than 2 Ha.	32,187	235,701	23,523	122,677	4,300	45,254	6,799	67,770
More than 2 less than 5 Ha	19,251	216,405	12,230	88,137	3,322	50,976	5,535	77,292
More than 5 less than 20 Ha	31,028	521,205	15,972	164,484	6,165	128,387	12,033	228,334
More than 20 less than 50 Ha	13,945	396,795	6,164	93,059	3,302	127,410	6,123	176,326
More than 50 less than 100 Ha	7,105	293,073	2,697	55,851	1,867	90,782	3,524	146,440
More than 100 less than 1000 Ha.	7,093	555,108	2,235	75,557	2,239	199,791	3,915	279,760
More than 1000 less than 2500 Ha.	113	31,238	25	2,130	51	17,990	63	11,118
More than 2500 Ha.	20	12,718	5	877	11	9,959	6	1,882
Only Private	184,531	2,931,066	117,211	842,118	33,759	995,829	48,240	1,093,119
Without Natural Pasture	125,196	1,354,648	84,890	477,910	21,151	475,291	27,300	401,447
With Natural Pasture	59,335	1,576,418	32,321	364,208	12,608	520,538	20,940	691,672
Less than 2 Ha.	12,414	99,307	9,109	46,730	1,690	23,569	2,516	29,008
More than 2 less than 5 Ha	8,631	99,422	5,637	39,593	1,521	28,549	2,235	31,280
More than 5 less than 20 Ha	16,029	285,199	8,859	90,780	3,291	79,334	5,531	115,085
More than 20 less than 50 Ha	9,937	291,594	4,522	68,648	2,412	95,921	4,211	127,025
More than 50 less than 100 Ha	5,821	247,045	2,207	46,768	1,570	79,375	2,849	120,902
More than 100 less than 1000 Ha.	6,367	511,546	1,956	68,788	2,055	186,639	3,526	256,119

Table A.3. (Continued) Units of Production and Inventory of Bovine Cattle per Land Tenure System and Farm Size

More than 1000 less than 2500 Ha.	102	29,587	22	2,024	48	17,192	57	10,371
More than 2500 Ha.	20	12,718	5	877	11	9,959	6	1,882
Only *Ejidal*	361,603	2,862,966	251,895	1,415,441	50,951	534,244	83,226	913.281
Without Natural Pasture	316,681	2,292,493	225,515	1,213,666	43,467	411,520	68,016	667,307
With Natural Pasture	44,922	570,473	26,380	201,775	7,484	122,724	15,210	245,974
Less than 2 Ha.	17,468	121,573	12,678	66,891	2,274	19,310	3,877	35,372
More than 2 less than 5 Ha	9,458	105,809	5,753	42,916	1,603	19,767	3,054	43,126
More than 5 less than 20 Ha	13,416	210,114	6,143	64,018	2,579	43,101	5,996	102,995
More than 20 less than 50 Ha	3,276	83,325	1,284	18,568	732	25,526	1,603	39,231
More than 50 less than 100 Ha	908	30,229	332	5,630	208	7,873	486	16,726
More than 100 less than 1000 Ha.	381	18,191	184	3,657	82	6,585	189	7,949
More than 1000 less than 2500 Ha.	-4	1,232	-2	95	-1	562	-2	575
More than 2500 Ha.	0	0	0	0	0	0	0	0
Mixed	35,064	328,222	23,654	135,343	6,037	76,676	8,338	116,203
Without Natural Pasture	28,568	212,870	19,502	98,554	4,864	49,389	6,481	64,927
With Natural Pasture	6,496	115,352	4,152	36,789	1,173	27,287	1,857	51,276
Less than 2 Ha.	2,305	14,821	1,736	9,056	336	2,375	406	3,390
More than 2 less than 5 Ha	1,159	11,174	838	5,628	196	2,660	246	2,886
More than 5 less than 20 Ha	1,581	25,892	968	9,686	295	5,952	506	10,254
More than 20 less than 50 Ha	732	21,876	358	5,843	158	5,963	309	10,070
More than 50 less than 100 Ha	376	15,799	158	3,453	89	3,534	189	8,812
More than 100 less than 1000 Ha.	338	25,371	93	3,112	97	6,567	198	15,692
More than 1000 less than 2500 Ha.	3	419	-1	11	2	236	1	172
More than 2500 Ha.	0	0	0	0	0	0	0	0
TROPICAL REGION	400320	8660876	215834	2431423	73469	2164781	143033	4064672
URBAN	3983	54771	1778	19058	1059	15468	1562	20245
RURAL	396337	8606105	214056	2412365	72410	2149313	141471	4044427
Without Natural Pasture	249796	4890826	145025	1494902	42698	1153628	81172	2242296
With Natural Pasture	146541	3715279	69031	917463	29712	995685	60299	1802131
Less than 2 Ha.	30357	330179	17830	133350	4920	67978	9795	128851
More than 2 less than 5 Ha	28355	355365	15090	134523	5019	73222	10430	147620
More than 5 less than 20 Ha	56933	983648	26418	319144	11029	216912	23873	447592
More than 20 less than 50 Ha	16753	614011	6130	137205	3979	160189	8344	316617
More than 50 less than 100 Ha	7067	475552	2004	76897	2189	151118	3783	247537

Table A.3. (Continued) Units of Production and Inventory of Bovine Cattle per Land Tenure System and Farm Size

More than 100 less than 1000 Ha.	6903	886775	1510	109154	2503	302922	3973	474699
More than 1000 less than 2500 Ha.	137	53152	36	5226	56	15255	87	32671
More than 2500 Ha.	20	16597	5	1964	6	8089	10	6544
Only Private	101685	4258948	44971	781140	23812	1411909	42166	2065899
Without Natural Pasture	54010	2013047	26320	387455	11780	686139	20349	939453
With Natural Pasture	47675	2245901	18651	393685	12032	725770	21817	1126446
Less than 2 Ha.	7101	105420	4260	31149	1118	29088	2181	45183
More than 2 less than 5 Ha	5916	108999	3049	30810	1101	30550	2221	47639
More than 5 less than 20 Ha	12968	354048	5366	85214	2988	104260	5763	164574
More than 20 less than 50 Ha	10072	442315	3245	85167	2735	130373	5170	226775
More than 50 less than 100 Ha	5696	403811	1489	62186	1840	134704	3083	206921
More than 100 less than 1000 Ha.	5790	774752	1210	93972	2193	277326	3320	403454
More than 1000 less than 2500 Ha.	105	44431	25	3809	42	12600	67	28022
More than 2500 Ha.	9	12125	1	1378	6	6869	2	3878
Only *Ejidal*	281558	4004941	162704	1547941	45969	656603	93962	1800397
Without Natural Pasture	188339	2705072	114721	1059981	29471	426294	58105	1218797
With Natural Pasture	93219	1299869	47983	487960	16498	230309	35857	581600
Less than 2 Ha.	22292	212964	13037	98218	3624	36061	7272	78685
More than 2 less than 5 Ha	21585	233441	11596	99813	3762	39490	7893	94138
More than 5 less than 20 Ha	42071	588974	20245	223617	7690	104759	17209	260598
More than 20 less than 50 Ha	5605	134888	2517	44034	1006	22500	2593	68354
More than 50 less than 100 Ha	926	45505	378	9791	230	10594	453	25120
More than 100 less than 1000 Ha.	702	72532	195	10535	173	13788	414	48209
More than 1000 less than 2500 Ha.	22	7133	8	1367	9	1897	15	3869
More than 2500 Ha.	0	4432	-1	585	0	1220	-1	2627
Mixed	13094	342216	6381	83284	2629	80801	5343	178131
Without Natural Pasture	7447	172707	3984	47466	1447	41195	2718	84046
With Natural Pasture	5647	169509	2397	35818	1182	39606	2625	94085
Less than 2 Ha.	962	11795	533	3983	178	2829	340	4983
More than 2 less than 5 Ha	854	12925	445	3900	156	3182	316	5843
More than 5 less than 20 Ha	1894	40626	807	10313	351	7893	901	22420
More than 20 less than 50 Ha	1074	36808	368	8004	236	7316	579	21488
More than 50 less than 100 Ha	443	26236	137	4920	119	5820	245	15496
More than 100 less than 1000 Ha.	406	39491	105	4647	137	11808	234	23036
More than 1000 less than 2500 Ha.	-3	1588	-1	50	-2	758	-1	780
More than 2500 Ha.	-2	40	-1	1	0	0	-1	39

Source: INEGI.

Table A.4. Characteristics of Intensive and Extensive Mexican Beef Production Systems

Types of Beef Enterprises	Average Herd Productivity		Feed and Nutrition	Sanitation	Technical Level of Enterprise
INTENSIVE					
Fattening	Initial Wt.	660 lbs	Balanced rations; Forages with vitamin, mineral and protein supplementation	High	High Use total confinement
	Final Wt.	880 lbs			
	Age at Slaughter	2 years			
	Dressing Percent	56 %			
	Capacity	200-500 hd			
Purebred Cow-Calf	Herd Size	200-350 hd	Balanced rations; Forages with vitamin, mineral and protein supplementation	High	High Use artificial insemination
EXTENSIVE					
Commercial Cow-Calf	Weaning Wt.	330 lbs	Pasture, grain stubble and agricultural byproducts	Low	Low
Stocker	Initial Wt.	330-400 lbs	Improved summer pasture, grain stubble and supplements	Low	Low
	Final Wt.	600-750 lbs			
	Duration	6-10 months			
	Herd Size	50-200 hd			
Fattening	Initial Wt.	400-460 lbs	Pastures with introduced grasses. Supplementation occurs only in some herds	Low	Medium
	Final Wt.	900 lbs			
	Duration	18 months			
	Dressing Percent	52%			
SEMI-INTENSIVE					
Dual Purpose	Produce meat and milk		Pastures with cultivated grasses, and natural summer pastures. Supplementation occurs only in some herds	Low	Medium Partial milking Deficient management skills
	Strong seansonality				
	Capacity				
	Milk production	35-50 hd			
	Lactation period	3 qts/day/hd			
	Weaning Wt.	60-180 days			
	Weaning Age	400-440 lbs			
		12 months			

Table A.4. (Continued) Characteristics of Intensive and Extensive Mexican Beef Production Systems

Type of Beef Enterprise	Breeds Used	Marketing	Level of Producer Organization	Geographic Location
INTENSIVE				
Fattening	European, mainly or crossed with Brahman	Local domestic markets and large cities	High	Arid and semiarid north, states bordering the U.S.
Purebred Cow-Calf	Purebred Brahman, Brown Swiss and Simmental	Inadequate because of high prices and many intermediaries	High	Dry and humid tropics, Tamaulipas, Veracruz, Tabasco, Chipas, Campeche and Yucatan
EXTENSIVE				
Commercial Cow-Calf	European breeds crossed with Zebu breeds	Export to the U.S., or fatten in the tropics	Low Frequently, not a member of any organization	Arid and semiarid north; temperate and mountainous central region
Stocker	European breeds crossed with Zebu breeds Marked Holstein influence in the center region	Local consumers, and supermarkets in large cities	Low Frequently, not a member of any organization	Arid and semiarid north; temperate and mountainous central region
Fattening	Brahman crossed with Brown Swiss, other Zebu breeds, and some Simmental	Domestic markets and supermarkets in large cities	Medium	Dry and humid tropics
SEMI-INTENSIVE				
Dual Purpose	Brahman crossed with Brown Swiss, other Zebu breeds and some Simmental	Calves are sold for fattening	Medium	Dry and humid tropics

Source: Cockerham.

Table A.5. Productivity Rates for Cows by Type in Mexico's Production Regions

	Arid Region		Temperate Region		Tropical Region	
Productivity Measure	Introduced Cows	Native Cows	Introduced Cows	Native Cows	Introduced Cows	Native Cows
Number of Cows	100	100	100	100	100	100
% Calving Rate	73.83	58.83	63.00	53.80	74.70	58.00
% Mortality Rate	5.00	5.00	5.00	5.00	5.00	5.00
% Weaning Rate[1]	70.14	55.89	59.85	51.11	70.97	55.10
Steer Calves Produced	35.07	27.94	29.93	25.56	35.48	27.55
Heifer Calves Produced	35.07	27.94	29.93	25.56	35.48	27.55
Weaning Weight (Steers)[2]	400	371	400	371	400	371
Weaning Weight (Heifers)[3]	384	356	384	356	384	356
Pounds of Steer/Cow	140.28	103.67	119.70	94.81	141.93	102.21
Pounds of Heifer/Cow	96.27	63.88	76.51	55.38	97.85	62.48

Source: [1] Montano-Bermudez. and Reynolds. [2] Reynolds and Magna. [3] Walker.

Table A.6. Land Area per State and per Land Tenure Classification in Mexico

Region	*Ejido* Land Area (ha)	Private Land Area (ha)	Total Land Area (ha)
Arid/Semiarid Region			
Baja California	5,113,394	1,881,673	6,995,067
Baja California Sur	5,051,062	2,290,598	7,341,660
Coahuila	6,284,397	8,714,164	14,998,561
Chihuahua	9,748,552	14,745,297	24,493,849
Durango	8,028,347	4,285,069	12,313,416
Zacatecas	3,629,978	3,688,526	7,318,504
Nuevo Leon	1,868,555	4,619,483	6,488,038
San Luis Potosi	3,717,396	2,593,972	6,311,368
Tamaulipas	2,398,191	5,542,839	7,941,030
Sonora	5,664,948	12,550,319	18,215,267
Arid Region Totals	51,504,820	60,911,940	112,416,760
Temperate Region			
Aguascalientes	240,297	307,077	547,374
Guanajuato	1,154,565	1,891,781	3,046,346
Hidalgo	912,550	1,166,152	2,078,702
Michocan	2,692,184	3,303,771	5,995,955
Jalisco	3,046,499	5,034,400	8,080,899
Mexico	1,068,096	1,068,096	2,136,192
Federal District	66,213	81,584	147,797
Oaxaca	7,412,619	1,982,335	9,394,954
Puebla	1,545,634	1,843,914	3,389,548
Queretaro	547,764	598,186	1,145,950
Tlaxacala	190,883	210,976	401,859
Temperate Regional Totals	18,877,304	17,488,272	36,365,576
Tropical Region			
Sinaloa	3,230,533	2,600,754	5,831,287
Colima	289,291	230,082	519,373
Guerrero	3,771,753	2,653,721	6,425,474
Chiapas	3,130,892	4,288,283	7,419,175
Veracruz	2,840,561	4,332,573	7,173,134
Tabasco	1,011,991	1,511,677	2,523,668
Campeche	3,115,750	1,967,040	5,082,790
Quintana Roo	2,743,286	2,281,047	5,024,333
Yucatan	2,162,147	1,678,256	3,840,403
Tropical Regional Totals	22,296,204	21,543,434	43,839,638
National Total	92,678,328	99,943,645	192,621,973

Source: Thompson, and Wilson

Table A.7. Population per State

State	Population [1] in 1990	Population [2] Adjusted to 1997
Arid/Semi-Arid Region	18,193,643	21,934,864
Baja California	1,660,855	2,002,382
Baja California Sur	317,764	383,107
Coahuila	1,972,340	2,377,919
Chihuahua	2,441,873	2,944,004
Durango	1,349,378	1,626,855
Zacatecas	1,276,323	1,538,778
Nuevo Leon	3,098,736	3,735,940
San Luis Potosi	2,003,187	2,415,109
Tamaulipas	2,249,581	2,712,170
Sonora	1,823,606	2,198,600
Temperate Region	42,451,218	51,180,607
Aguascalientes	719,659	867,645
Guanajuato	3,982,593	4,801,547
Hidalgo	1,888,366	2,276,677
Michocan	3,548,199	4,277,827
Jalisco	5,302,689	6,393,099
Mexico	9,815,795	11,834,250
Federal District	8,235,744	9,929,288
Oaxaca	3,019,560	3,640,482
Puebla	4,126,101	4,974,565
Queretaro	1,051,235	1,267,404
Tlaxacala	761,277	917,821
Tropical Region	18,585,082	22,406,796
Sinaloa	2,204,054	2,657,281
Colima	428,510	516,626
Guerrero	2,620,637	3,159,528
Chiapas	3,210,496	3,870,681
Veracruz	6,228,239	7,508,973
Tabasco	1,501,744	1,810,553
Campeche	535,185	645,237
Quintana Roo	493,277	594,711
Yucatan	1,362,940	1,643,206
National Total	79,229,943	95,522,266

Source: [1] Pick and Butler. [2] SAGAR.

Table A.8. Cost of Transportation for Feeder Calves and Fed Calves

Feeder Calves	Mileage[1]	Rate/Mile	A.U./ 30,000# Load	Cost/head
400# Steers				
R1-R2	931	$1.50	75	$18.62
R1-R3	1440	$1.50	75	$28.80
R2-R3	509	$1.50	75	$10.18
371# Heifers				
R1-R2	931	$1.50	81	$17.27
R1-R3	1440	$1.50	81	$26.71
R2-R3	509	$1.50	81	$9.44
384# Steers				
R1-R2	931	$1.50	78	$17.88
R1-R3	1440	$1.50	78	$27.65
R2-R3	509	$1.50	78	$9.77
356# Heifers				
R1-R2	931	$1.50	84	$16.57
R1-R3	1440	$1.50	84	$25.63
R2-R3	509	$1.50	84	$9.06
Fed Calves				
950# Steer				
R1-R2	931	$1.50	32	$44.22
R1-R3	1440	$1.50	32	$68.40
R2-R3	509	$1.50	32	$24.18
934# Heifer				
R1-R2	931	$1.50	32	$43.48
R1-R3	1440	$1.50	32	$67.25
R2-R3	509	$1.50	32	$23.77
950# Steer				
R1-R2	931	$1.50	32	$44.22
R1-R3	1440	$1.50	32	$68.40
R2-R3	509	$1.50	32	$24.18
900# Heifer				
R1-R2	931	$1.50	33	$41.90
R1-R3	1440	$1.50	33	$64.80
R2-R3	509	$1.50	33	$22.91

Source: [1] Noble.

Table A.9. Variety Meats as a Percentage of the Carcass Meats

Item	Pounds per 1200 lb. Steer[1]	Variety Meat % of Steer	Pounds per 1100 lb. Cow[2]	Variety Meat % of Cow
Tongue	0.26	0.0002	0.32	0.0003
Cheek Meat	0.32	0.0003	0.43	0.0004
Head Meat	0.13	0.0001	0.14	0.0001
Oxtail	0.16	0.0001	0.2	0.0002
Hearts	0.38	0.0003	0.46	0.0004
Lips	0.11	0.0001	0.13	0.0001
Liver	0.96	0.0008	0.9	0.0008
Tripe, scalded edible	0.65	0.0005	1.06	0.0010
Tripe, honeycomb bleached	0.15	0.0001	0.14	0.0001
Total Pounds of Variety Meats	3.12	0.0026	3.78	0.0034

Source: [1] USDA-Market News, 1 September 1999. [2] USDA-Market News, 27 August 1999.

Table A.10. Values for Forage by Land Tenure and Region

Regions	Forage for Native Cattle $/AU	Forage for Improved Cattle $/AU
Arid/Semiarid Region		
Private Land	$12.00	$11.32
Ejido Land	$10.00	$8.89
Temperate Region		
Private Land	$12.00	$10.00
Ejido Land	$13.33	$8.00
Tropical Region		
Private Land	$15.00	$13.33
Ejido Land	$26.67	$16.00

VITA

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