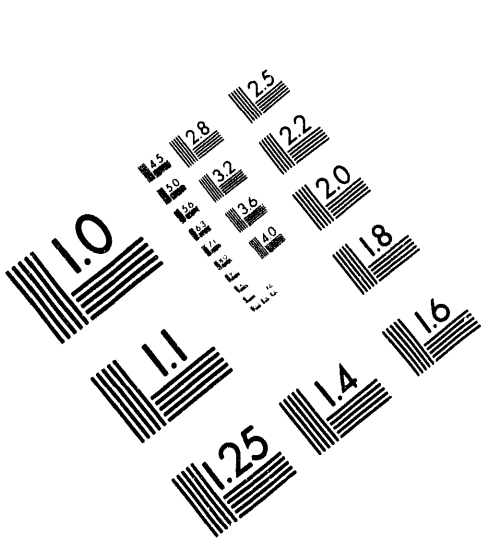

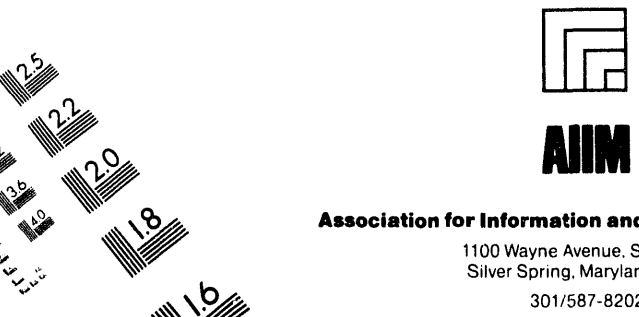

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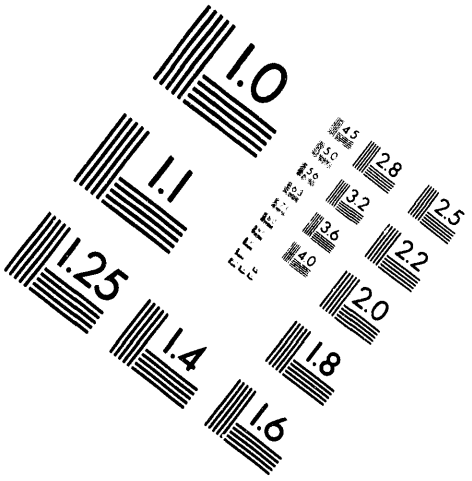

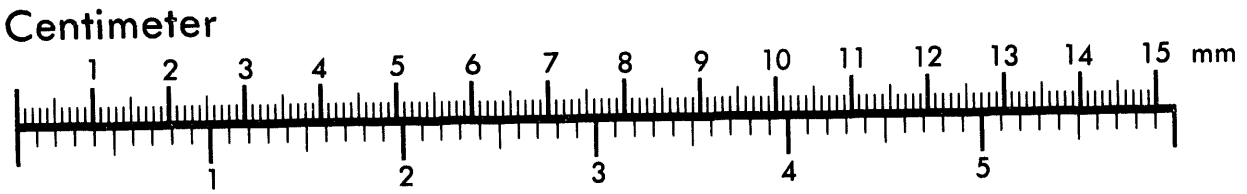

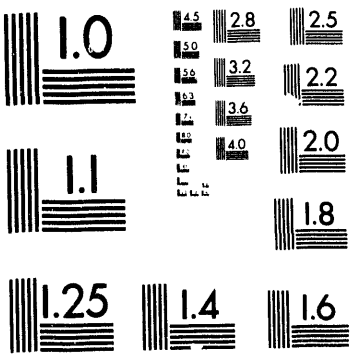

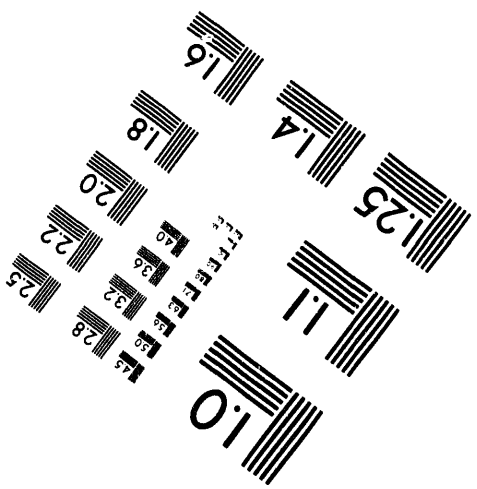

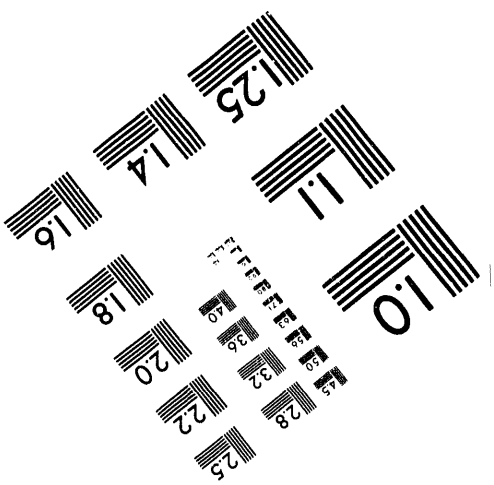

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DUST BOWL MIGRATION AS AN ANALOG FOR POSSIBLE GLOBAL WARMING-INDUCED MIGRATION FROM MEXICO

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EXECUTIVE SUMMARY

As a result of global increases in CO_2 and other "greenhouse gases," scientists have predicted that increases in mean temperatures are likely worldwide. Current climate theory suggests that such increases may result in rising sea level, and changes in the frequency of droughts and tropical storms. If we can understand the possible impacts of global warming-induced drought and factors that aggravate or mitigate those impacts, we can propose strategies that will alleviate negative responses such as migration.

The question of how global warming could affect Mexico can be illuminated by a comparison study of the effects of drought on the Dust Bowl region of the U.S. Great Plains in the 1930s and Mexico's arid agricultural regions. Five categories compose a framework for comparing the two regions:

- environment, including climate and geography
- agricultural practices
- economics
- social structures
- government programs and interventions.

Environment: The Dust Bowl area and Mexico (see map) show striking similarities in their vulnerability to drought. The two agricultural regions have semiarid to arid climates. Major droughts have afflicted both areas. For the Great Plains, major droughts have occurred in every other decade since the 1870s. Mexico historically suffers drought in at least one state every year and suffers regional drought in 3 of every 10 years. Geographically, the Dust Bowl area is level land, but in Mexico 61 percent of arable land in rainfed districts slopes at a 4 percent grade.

Agricultural practices: In the 30s, farmers in the Dust Bowl area aggravated the effects of drought by disking, stubble burning, and overgrazing, all of which contributed to soil erosion. In addition, the introduction of mechanization favored monocropping (wheat), which depleted the soil and allowed pests to proliferate. Finally, tenant and suitcase farmers continued these harmful practices, since they had no strong commitment to the land. Similar to the Dust Bowl situation, Mexico does not practice soil conservation, so erosion is a constant problem, especially on the slopes. In Mexico as in the U.S., mechanization has favored monocropping, though subsistence farmers still grow maize and beans together. Differences between the two regions include Mexico's use of irrigation on the land oriented towards export crop production (20% of agriculture) and hybrid cultivars.

Economics: In 1930, the total population of the United States was 122,775,000; about 25 percent of the population was engaged in agriculture. In Mexico today about 25 percent of Mexico's 85,000,000 people are engaged in agriculture. In the Dust Bowl, drought exacerbated poor economic conditions; adding to the problem, farmers grew as much wheat as they could, saturating the market and driving down the price. General economic conditions in Mexico are impossible to predict at the time global warming is likely to be felt, but the current economy is depressed.

Large farms withstand the effects of drought better than small farms, so Mexico's numerous subsistence farmers would likely be particularly hard hit. Today's Mexican small farms (average 30

acres) are much smaller than family farms at the start of the Dust Bowl years (average 320 acres). Even large Mexican family farms are, on average, only about two-thirds the size of large American farms during the 1930s. Furthermore, the trend in Mexico has been toward smaller farms to increase ownership and lately to encourage city dwellers to move to rural areas.

Farmers feeling the effects of drought need bank loans, which were hard to get during the Dust Bowl years and are even harder to get for small farmers in Mexico, many of whom did not own their land until recently (and thus had no collateral).

Government programs and interventions: The U.S. had few formal programs that responded to drought conditions at the start of the Dust Bowl years and no history of intervening under drought conditions. Gradually loans and subsidies were instituted. Mexico's current policies will not support farmers under drought conditions. reduce credit for small and medium scale producers, privatize input industries, abolish support prices, and liberalize trade, except for maize and beans. However, Mexico has a recent history (1980-1982) of providing the kind of government support that would help farmers weather drought.

Emigration as a response to drought: Emigration was one of several responses to drought during the 1930s but is expected to be a larger portion of Mexico's response to drought conditions under global warming. Migration in the U.S. in the 30s was fueled by the Great Depression probably more than by drought; of the approximately 3 million migrants, only a minority came from farms. Incentives to stay on the farm probably included a strong tradition of family farm ownership and a realization that economic conditions were no better off the farm. Mexico, in contrast, has sent a steady stream of migrants and emigrants to the U.S. Historically the number of migrants and emigrants rises under drought conditions and other economic stresses in Mexico. Moreover, Mexican farmers have no strong tradition of land ownership and generally see that conditions in the U.S. will be better, i.e., they will find work. This pattern is expected to continue under global warming-induced drought, with increasing numbers of environmental refugees emigrating from Mexico to the U.S.

DUST BOWL MIGRATION AS AN ANALOG FOR POSSIBLE GLOBAL WARMING-INDUCED MIGRATION FROM MEXICO

TABLE OF CONTENTS

DUST BOWL MIGRATION AS AN ANALOG FOR POSSIBLE GLOBAL WARMING-INDUCED MIGRATION FROM MEXICO

INTRODUCTION

Global Climate Change

As a result of increases in CO_2 and other radiatively important trace gases, scientists have predicted increases in mean worldwide temperatures of 2-5 degrees C over the next 50 to 100 years. Such temperature increases may result in climate modifications that would in turn be associated with increases in drought and desertification and could even change the patterns of the monsoons and tropical rains, which are important to agriculture throughout the world (Leaf 1989; USEPA 1986). The predicted that the rise in sea level caused by melting and thermal expansion of glaciers and polar icecaps could flood large population centers, destroying habitation and displacing populations. This will result in approximately 50 million "environmental refugees" worldwide, triple the number of today (Leaf 1989).

The expected shifts in precipitation are also likely to result in 1) increased runoff contaminated with pesticides, salts, garbage, sewage, and eroded soil, and 2) drought also leading to increased soil erosion and salinization, as well as depletion of limited water resources. Some land may become unfit for agriculture because of saltwater incursions into water tables, and some water supplies may no longer be potable for the same reason.

The total impact of global warming on agriculture and human habitation could considerably slow the economic development of some nations and would particularly affect agricultural production. Loss of homes, the inability to raise food, an increased prevalence of disease and worsened economic conditions may drive people to leave their homelands, seeking entry into countries which have more resources and greater resistance to the economic consequences of climatic change.

Global Climate Change and Immigration

Unequal access to resources has always been a major force driving people to migrate (Ehrlich and Ehrlich 1990). In poor countries, the degradation of the environment arising from global climate change will likely exacerbate the disparity between rich and poor citizens. Many of the poorer people would become "environmental refugees," seeking entry into other more economically secure countries, including the United States. Some will seek legal entry; a far greater number, however, is more likely to attempt illegal entry into the U.S. Since the U.S. is a wealthy nation adjacent to a poor nation--Mexico--the influx of migrants should continue to increase (Ehrlich and Ehrlich 1990). This has already happened once in recent history: in 1982, as the Mexican economy deteriorated due to the collapse of global oil prices, the number of illegal immigrants apprehended while trying to enter the U.S. increased significantly (Bean, Edmonston, Passel 1990). The extent to which migration will be driven by global environmental change may be difficult to assess, since it will take place against a backdrop of migration induced by social, economic, and political factors. Indeed, environmental factors have a great impact on the economic, social, and political stability of a given nation over time. Thus, because it impacts all sectors of society, global climate change is likely to influence migration.

Owing to its proximity to Latin America and its economic prosperity, the U.S. will be a likely destination for emigrants from Mexico and from South and Central America who are seeking lives with more economic, social, and/or political stability. Immigrants are important to the productivity of the United States; as the U.S. birth rate continues to drop, economic growth will require laborers to fill low-wage jobs. Because illegal immigrants usually have low socioeconomic standing, often speak little or no English, and lack education and work skills, they often accept the low-wage jobs which are shunned by the native populations. A massive influx of Mexican immigrants could profoundly affect the social structures and economies of both the U.S. and Mexico.

Global Climate Change - Lessons from the Past

Population shift resulting from climate change has had several precedents. Archeological excavations have revealed that the collapse of the ancient Akkadian Empire in southern Mesopotamia about 2,400 years ago was most likely caused by an abrupt shift in climate. Analyzing soil samples for past moisture content, researchers have concluded that as wheat and barley crops in the north began to dry up, thousands of northern settlers migrated southward, where they strained southern food and water supplies. The resulting sudden chaos precipitated the ultimate downfall of the empire (Gibbons 1993).

In the western hemisphere, global climate change also may have significantly contributed to the devastation of several ancient South American civilizations, including the Moche culture in what is now northern Peru. Scientists report that drought recorded in a glacial ice core between 560 and 590 AD corresponds to a sharp decline in the Moche culture. It appears that the capital city was flooded, rebuilt, and then overrun by sand dunes brought about by drought. The people migrated north in response to these conditions (New Scientist 1990).

In more recent times, the United States also experienced a large population shift resulting from changing weather patterns. This occurred during the drought of the 1930s, which many experts believe was the most devastating drought to hit North America since the early 17th century. Over a ten-year period, extremely dry conditions caused several million people in a broad region of the country to leave the land, moving into towns and cities or heading toward the coasts. Subsequent droughts, e.g., in 1970, caused far less migration mainly because infrastructure changes made by the U.S. government. Because of these differences in impact, then, U.S. droughts may provide useful information to develop responses to possible future drought conditions in Mexico, since Mexican migration directly impacts the United States in many ways.

Using such indicators as climate, the environment, economics, and agricultural systems, this paper will examine the drought of the 1930s in the U.S. and government responses, the expected climate change in Mexico, and the Mexican agricultural and economic systems, in order to determine what relevance U.S. responses to drought may have for Mexico under anticipated climatic changes. The comparisons between the U.S. and Mexico are not exact, because the two countries differ in terms of agricultural systems (the Mexican *latifundio* or *ejido* versus the American family farm) and in terms of the technologies available to each country in times of drought. In addition, the U.S. government of the 1930s operated quite differently from the Mexican government of today. The U.S. experience may, however, provide some useful insights for assessing possible future conditions in Mexico, insofar as it suggests options for the U.S. and Mexico to modify potential migration.

PART I - THE U.S. GREAT PLAINS

The drought in the Great Plains region of the United States was a major catalyst for migration and social change during the 1930s. Drought exacerbated poor economic conditions and brought to light previously unaddressed weaknesses of the U.S. agricultural system. Until the drought occurred, for example, many farmers, in pursuit of rapid economic gain, chose to ignore the effects of their farming practices on the land; consequently they used techniques which degraded the soil and led to severe erosion. This erosion, intensified by the dry weather and high winds prevalent during the drought years, further contributed to the agricultural crisis that followed.

The severe economic conditions of the 1930s made the plight of Great Plains dwellers even more difficult. While some of the more well-to-do farmers would perhaps have been able to withstand the drought by itself, the combination of drought and economic depression forced many to abandon their land in search of employment opportunities elsewhere; nine million acres of farmland went back to nature (Worster 1979). It is estimated that over three million farm families emigrated from the Great Plains region during the 1930s (Worster 1979).

Farmers of the 1930s also lacked the technology and financial support of the government which would have enabled them to remain on their land during the drought. While many federal relief programs were initiated during the 1930s, this assistance came too late for many farmers.

However devastating conditions may have been during the 1930s, they nonetheless provided the impetus for major changes in the U.S. agricultural system--changes that would help reduce the impacts of future droughts on farmers and their communities. When drought struck again four decades later, five major changes had occurred to help mitigate the drought's effects:

- Farmers were practicing more environmentally sound methods of tilling, planting, harvesting, and grazing; and thousands of acres of submarginal land had been taken out of production.
- More effective pesticides and drought-resistant hybrids of wheat and corn had been developed.
- Government programs--including loans, crop insurance, and financial incentives, such as payment-in-kind programs--were in place by this time to help cushion farmers against drought's impacts.
- The United States was in a better overall position economically during the 1970s than it was during the 1930s; farmers did not have to cope with an economic depression in addition to drought. Rural communities had also developed more diverse economic bases by this time so that a few years of bad yields would not ruin the local economy altogether.

- Farms were larger than in previous decades. Average farm size in the Dust Bowl was just under 320 acres[1]; in 1970 it was over 1,000 acres and, in general, larger, more heavily capitalized farms tend to be better able to withstand economic hardship than smaller ones.

This section of this study will compare and contrast two major U.S. droughts--the so-called "Dust Bowl[2]" of the 1930s and the drought of the mid-1970s--to demonstrate that the negative impacts of drought can be alleviated or "lessened" by a combination of governmental intervention and responsible land management.[3]

The second section of this paper will compare the drought of the 1930s with current agricultural conditions in Mexico to see how possible global warming scenarios, in which droughts could increase in length and severity, might impact Mexican immigration into the United States.

Climate and Geography

The Great Plains region of the United States stretches from approximately the 100th meridian in the east to the Rocky Mountains in the west and includes parts of North and South Dakota, Nebraska, Kansas, Montana, Oklahoma, Wyoming, Colorado, Texas, and New Mexico. This land is for the most part level, sloping gradually upward from east to west.

The southern Plains region is classified as semiarid, typically receiving a range of 625-900 mm (25 to 36 inches) and an average of 750 mm (30") or less of precipitation per year (USDA 1979). The climate is often unpredictable, and the region is known to experience extremes of heat and cold, as well as droughts, floods, tornadoes, and blizzards. This volatile climate is caused by the interaction of three major forces: mild, dry air moving across the western mountains; cold, dry fronts pushing down from the Arctic; and warm, moist currents flowing upward from the Gulf of Mexico (Worster 1979).

The soils of the southern Great Plains are nutrient-rich. Because of the dry climate, few trees grew in the region, except along river bottoms, until settlers began to plant shelterbelts in the late 19th century. Native vegetation includes short grasses such as blue grama and buffalo grass and shrubs.

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[1] The average farm size is somewhat higher in the Great Plains area than in other parts of the U.S. because of the many ranches there (Worster 1979). While average farm size in the Great Plains was around 320 acres in the 1930s, it was only 157 acres for the U.S. as a whole (Johnston et al. 1987).

[2] Strictly speaking, the "Dust Bowl" refers to a 97-million-acre portion of the Great Plains, consisting of the Texas and Oklahoma panhandles, eastern New Mexico, southeastern Colorado, and southwestern Kansas. This was the area most severely affected by the 1930s drought. While this paper is concerned with drought in the entire Great Plains region, it draws heavily on data from the "Dust Bowl" region.

[3] The concept of lessening was originally developed by Richard A. Warrick of Clark University.

Much of the land is in range, used for grazing beef cattle, and about one-third of the area is dry-farmed to winter wheat, grain sorghum, and cotton (USDA 1981).

Drought Conditions in the Great Plains - 1930s

As mentioned, drought has been a prominent feature of the Great Plains states for thousands of years. Tree-ring analysis has indicated that drought occurred in the region long before European settlers arrived and began keeping written records. Over the past century and a half alone, major droughts afflicted this broad area in the 1860s, 1870s, 1890s, 1910s, 1930s, 1950s, 1970s, and again in the late 1980s. The episodes of the 1890s and 1910s were so severe, in fact, that people actually starved to death, and thousands of newly-arrived settlers abandoned their holdings and either returned to the east or moved westward. Between 1888-1892, large segments of the Great Plains were virtually depopulated (Porter 1989). The drought of the 1930s was unique in its duration and severity.

Climate One means of measuring the severity of unusually wet or dry weather in a given location is the Palmer Index, which considers the separate effects of precipitation, soil moisture, and temperature. Values of +/- 2 indicate normal conditions, while readings of +/- 8 represent extremes. Values more negative than -4 indicate drought (Porter 1989). The southern Plains region, with mean annual precipitation of approximately 30 inches had PDI values of -3 to -5 during the summer of 1934. In the northern Great Plains and western Corn Belt, PDI values were -6 to -8 (Felch 1978). Temperatures during the 1930s were also higher than normal in the Great Plains and higher than those recorded in the five decades since. On the average, temperatures for the decade of the 1930s were 1 degree C above normal (CAST 1992). The most severe drought years were 1934 and 1936, when in certain locations, mean temperatures were 4 or more degrees above normal.

Dust storms which carried millions of tons of topsoil across the plains were a prominent feature during this decade. These storms were caused by the prevailing dry weather and wind, but were made worse by agricultural practices that broke the soil down into very fine particles. Winds of up to 60 miles per hour would carry dust for hundreds of miles, in some places creating dunes five or six feet high and leaving behind exposed hardpan.[4] In 1935-36, the storms damaged 50 million acres of farmland throughout the Great Plains area (Hurt 1981).

Population In 1930, the total population of the United States was 122,775,000; about 25% of the population was engaged in agriculture (USDA 1972). Approximately 43% of the population in the West South Central states was on farms (USDA 1940). (These states, so designated by the USDA, correspond closely to the Great Plaiin states). By 1937, this percentage had declined to 41% (USDA 1972). Of these farmers, 41.1% were tenant farmers in 1935 (USDA 1937). The state of Kansas, for example, had a population of 1.88 million in 1930 and a total of 166,000 farms (UKS 1993; USDA 1993). Ten years later, the state's population was 1.80 million and the number of farms had fallen to 159,000 (UKS 1992; USDA 1991).

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[4] The hardpan is the hard, unplowed ground below the topsoil.

The average farm family consisted of 6.7 persons in 1935. Average farm income was $1,552 per family farm, compared with $2,020 for the rest of the population (USBC 1975).

Crop Yields The drought significantly impacted crop yields. Average wheat production in the Great Plains fell by one-third[5] during the 1930s, and over the course of the decade nearly 30% of the wheat crops planted were abandoned rather than harvested (CAST 1992). Production of corn, sorghum, and other crops also declined during this decade.

Livestock Cattle suffered severely during the drought. Because of a shortage of feed crops, forage, and water, thousands of head of cattle died from dehydration or starvation. Others were sold to the government and slaughtered for canning under the Emergency Cattle Purchase Program created in 1934. Over 800,000 head of cattle from the Dust Bowl region were purchased by the government in an effort to keep cattle producers in business and to prevent additional starvation of livestock. The beef was canned and distributed through federal relief agencies around the region (Hurt 1981).

Pests Dry conditions were extremely conducive to the proliferation of pests, such as beetles and grasshoppers. The problem was particularly severe in 1937 and 1938, when wave after wave of grasshoppers attacked the five-state area of Kansas, Oklahoma, Texas, New Mexico, and Colorado, causing extensive damage to wheat crops. In Beaver County, Texas, government agencies and private citizens worked together to spread more than 175 tons of grasshopper poison around the region (Bonnifield 1979). Other pests such as army worms, jack rabbits, and boll weevils also caused severe damage in drought-affected areas.

Health Several people were known to perish in the dust storms. But the real health threats during these years were the respiratory infections that were aggravated by the blowing dust. A high silica content in the dust irritated the mucous membranes of the respiratory system, cutting into the lung tissue and lowering the body's resistance to disease. The dust contributed to infections such as sinusitis, pharyngitis, laryngitis, and bronchitis (Hurt 1981). The common term for these illnesses was "dust pneumonia," and in many cases the affliction even led to death. Dust pneumonia became something of a epidemic in 1935, prompting the Red Cross to set up a series of emergency hospitals

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[5] Part of the reason for this decline in production may also have to do with the "farm allotment" that was put into place by the government to reduce overproduction, which in the 1920s had led to extremely low prices in the early 1930s. In the spring of 1933 Congress created the Agricultural Adjustment Administration (AAA) to reduce production of wheat and other crops. Under the "allotment," farmers voluntarily agreed to reduce production by 15%. In return, they received payments from the federal government. Between 1933 and 1937, AAA checks represented the major source of income for Dust Bowl farmers. In 1935, 1.2 million individual farmers in 40 states participated in the program; government payments amounted to approximately $120,000,000. Without the AAA, the rate of farm failure and abandonment would certainly have been much higher (USDA 1934).

in Colorado, Kansas, and Texas (Bonnifield 1979). During that year, four Dust Bowl hospitals admitted 233 people suffering from respiratory diseases; of those patients 33 died (Hurt 1981).

Migration As a result of the extremely difficult conditions brought about by the drought, forced farm sales in the Great Plains were common. Sales due to bankruptcy constituted 37% of all farm transfers in 1932, compared with 27% only four years earlier (USDA 1934). Thousands of farmers and their families sold their holdings and emigrated into other areas of the country--California and Oregon were particularly common destinations. The states of Texas, Oklahoma, Kansas, and Nebraska were the hardest hit. Oklahoma alone lost 440,000 people, or 18.4% of its total population. Net loss in Kansas was 227,000 people (Worster 1979). Overall, almost a million people left the Plains during the first half of the decade, and another 2.5 million left after 1935. More than nine million acres were left fallow as a result of emigration. (Worster 1979).

Tenant farmers, because of their poverty, were among those most likely to emigrate. Many tenants were evicted by their landlords after the Agricultural Adjustment Administration (AAA) began to require farmers to reduce their acreage under cultivation. Some landlords chose to operate their farms themselves using machinery, while others hired laborers. In any case, by 1940 the number of tenant farmers in Oklahoma, Arkansas, and Texas had been reduced by 24% (Gregory 1989).

It is important to note that not all emigrants during this time were farmers. Indeed, because of their strong ties to their land, which in some cases stretched back for generations, most farmers from the Great Plains region chose to stay on the farm, rather than to take their chances in a new environment. Many of the migrants from the Plains region were town-dwellers, including schoolteachers, bankers, merchants and civil servants, among others. Up to one in six migrants were from non-farm professions (Gregory 1989).

Drought Conditions in the Great Plains - 1970s

Climate The drought of the mid-1970s was shorter than the drought of the 1930s. It began in the Southwest in the spring of 1974. PDI values at the onset of the drought were -2.0 to -3.0. During the summer months which followed, average temperatures in most of the region were 8-14 degrees C above normal (Wilhite and Rosenberg 1984c). Although 1975 was a normal year throughout the region, drought returned in 1976, when precipitation was 10% of normal in some parts of the western U.S. and 50% of normal in the southwest. In northeastern South Dakota, one of the most severely affected areas, PDI values were -7.0 (Wilhite and Rosenberg 1984c).

Temperatures throughout the region also ranged from 2-10 degrees above normal in both 1976 and 1977 (Wilhite and Rosenberg 1984c). The states most affected by the drought during those peak years were North and South Dakota, Minnesota, Wisconsin, and Michigan.

The states of Oklahoma, Colorado, New Mexico, Texas, and Kansas all experienced intense wind erosion in the 1970s. Nearly six million acres of land were severely damaged in these states during 1977. However, these storms were neither as frequent nor as damaging as the storms of the 1930s, largely because adjustments in farming methods significantly reduced the tendency of soils to erode (Worster 1986).

Population In 1972 the total population of the United States stood at 209,386,000; 4.6% of the population was engaged in agriculture. By 1978, farm population had declined to 3.6% (USDA 1987). The state of Kansas had 87,000 farms in 1970; by 1980 there were only 75,000 farms (USDA 1993). While this decline in the number of farms is even more dramatic than in the 1930s, farm numbers in the U.S. had been declining steadily since the 1920s, though the average farm size was increasing. Thus the decline was part of an ongoing trend. Presently, approximately 1.8% of the U.S. population is engaged in agriculture (USDA 1992).

Crop Yields Crop yields fell during the drought, though not as much as during the 1930s. Wheat yields during the drought were 17% below normal levels (Warrick 1980). Part of the reason for this more moderate decline was the milder character of the drought; however, adaptations in farming techniques, such as improved pest control, drought-resistant hybrids, and the expansion of crops' geographic extent, also helped minimize losses (CAST 1992).

Farming Practices during Drought - 1930s

Erosion The dry weather and strong winds of the 1930s caused millions of acres of natural cover, including buffalo and grama grass, to wither and die, exposing rangelands to severe wind erosion. The southern Plains states suffered the greatest losses, since frost and snow cover in the northern regions offered some protection from wind.

Farmers also contributed to erosion through their farming practices. Although most of them had a general understanding of the causes of erosion, they nonetheless continued their traditional methods of farming, which included monocropping, disking, and stubble burning.[6] They also allowed rangelands to be overgrazed by cattle. Over time these practices contributed to the loss of many acres of valuable cropland.

Mechanization Soil erosion and dust storms were worsened by a long-term trend toward mechanization. In the 1910s, demand for U.S. agricultural products rose dramatically because of the war in Europe. High wartime income drove a demand for better technologies in order to expand the acreage under cultivation. As new technologies became available, farmers made capital investments in tractors, plows, and other implements. Mechanization and expansion continued into the 1930s. However, Dust Bowl conditions made the problems of mechanization clear: more cultivated land meant more land exposed to the risk of erosion. The new combines encouraged monocropping of wheat, since wheat is well suited to combine harvesting. In addition, the new, more advanced machinery contributed to the dust storm problem by breaking the soil down into extremely fine particles which could be carried by the wind.

[6] This practice consisted of burning off the stubble left on a field at the end of each year. While this procedure reduced the cost of farming the land by killing weeds, it also reduced organic material in the soil. As a result, the soil lost much of its ability to absorb moisture.

The 1930s saw a proliferation of tractors, combines, one-way plows, and trucks. In 1915, for example, there were approximately 3,000 tractors in Kansas. By 1935 the figure stood at 71,000 (Bonnifield 1979). Tractors replaced teams of horses, making it possible to cultivate land previously reserved for pasture. Farmers could now sow and harvest much more wheat in much less time. Likewise, trucks made it possible to haul considerably more grain to market faster than before. In 1920, Kansas farmers used 3,900 trucks; ten years later 33,700 trucks were in use (Bonnifield 1979).

Like the truck and tractor, the combine also helped define agricultural trends during the 1930s. Early combines were not useful for harvesting crops such as maize and kafir. In order to take full advantage of the new technology, then, many farmers began to grow only wheat, which is well suited for combine harvesting. Once a sizeable investment was made in wheat-harvesting equipment, it was uneconomical to switch to other crops. In fact, farmers had to plant more acreage in order to be able to pay for the new machinery. The case of Hamilton County, Kansas, illustrates the dramatic rise in wheatcropping: in 1929 there were 16,641 acres of wheat under cultivation. Just two years later, some 103,787 acres were dedicated to wheat crops. (Bonnifield 1979). This extensive monocropping of wheat, which is a nutrient-depleting crop, ultimately led to soil degradation and also contributed to market saturation. In 1931 the price of wheat crashed to 25 cents a bushel, down from $2.50 per bushel a decade earlier. Land values also fell during the 1930s as a result of rapid farm expansion.

Another invention which altered the character of Depression-era agriculture was the one-way disc plow, which by 1930 had become the most widely used plow in the Dust Bowl region. The one-way plow was significantly wider than the traditional model, which made it possible for farmers to till many more acres in a shorter period of time. The disks of the plow, moreover, left behind a very smooth, pulverized soil which required no separate disking or harrowing. This increased wheat yields, but it also broke down the soil structure, making the fine soil vulnerable to wind erosion (Bonnifield 1979).

Farm Type Most of the farms in the Great Plains were individually-owned family farms. However, there were also many tenant farmers in the southern regions. In 1930, for example, over 60% of farms in Oklahoma, Arkansas, and Texas were operated by tenant farmers. (Gregory 1989). The system of tenancy farming also had an impact on Dust Bowl conditions, for in order to meet their financial obligations to their landlords, these operators needed to raise cash crops, as opposed to soil-conserving crops, which include sudan grass, cane and sorghum. In addition, they had no stake in any improvements which they could make on the farms; if they were to lose their lease, for example, they would not have been compensated for their efforts. As a result, most tenant farmers did not bother to take measures to protect the land. Many tenants also frequently moved from farm to farm, leaving seriously degraded land behind them as they went (USDA 1937b).

Likewise, "suitcase" farming also contributed to land degradation in the Great Plains area. Suitcase farmers were those whose primary source of income was nonagricultural. These people generally lived in towns and cities and only visited their farms occasionally or hired laborers to work the land as needed. This meant that their commitment to the land was not as strong as that of full-time farmers. Consequently, if a crop did not look profitable, suitcase farmers could afford to abandon it altogether; once they abandoned their fields, they seldom made an effort to apply the appropriate soil conservation techniques (Hurt 1981).

Coping with Drought Once the drought was fully underway, farmers tried their best to combat its effects. Measures taken included crop diversification, returning some farmland to grassland, using cover crops, contour plowing, rotating crops, and planting shelterbelts. They also began strip cropping, which involved planting a close-growing, soil-holding crop, such as wheat, alongside strips of thickly growing crops, such as grain sorghum or sudan grass, which protected the wheat from wind (Hurt 1986). Legislation was also introduced to fine farmers who left their fields bare, since this led to erosion. In some cases, the federal government began to purchase private land in order to rehabilitate it. In other cases, land once owned or managed by smaller farmers (those with less than 320 acres) was purchased by larger enterprises (Bowden 1977). In general, New Deal farm policies encouraged small farmers to sell their land to more affluent farmers who possessed greater capital reserves and more sophisticated technology, such as tractors, plows, and combines. Erstwhile farmers moved into towns or left the Great Plains region altogether.

By the mid-1930s, some farmers began to irrigate in order to minimize the effects of drought. In 1939, for example, 83,000 acres in the state of Kansas were irrigated, as were 474,000 acres in Nebraska (USDA 1977). By and large, however, irrigation was not widely practiced because of high costs and technological constraints.

Farming Practices during Drought - 1970s

The drought of the 1930s had taught both farmers and policy-makers alike many valuable lessons. By the 1970s farmers had a better understanding of the relationship between farming practices and soil conservation and were able to use more environmentally responsible agricultural methods such as crop diversification, strip-cropping, minimum tillage, terracing, contouring, stubble mulching, shelterbelts, and grazing management. They also altered the kinds of crops they planted in order to minimize the possibility of drought damage. For example, they had considerably more acreage in wheat--particularly winter wheat--than farmers of the 1930s. A major advantage of winter wheat is that it is planted in the fall and harvested in the early summer before the onset of heat and possible drought (CAST 1992). 1970s farmers also diversified their crops so that they would not face financial ruin if a wheat crop failed.

Irrigation By the 1970s farmers also benefited from large-scale irrigation, which was used primarily for corn crops. Although some of the wealthier farmers had irrigated during the 1930s, using small wells, technological problems and high costs kept irrigation from becoming widespread at that time. By the 1950s, however, irrigation systems became more convenient with the introduction of aluminum and gated pipe and center-pivot sprinklers, inexpensive aluminum piping, deep well pumps, and low cost energy to run gasoline or natural gas engines (Opie 1992). Farmers increasingly viewed irrigation as a means of ensuring a profitable harvest during dry years. Thus, between 1949 and 1969 the area of irrigated land in the southern Great Plains expanded by 4.4% per year (CAST 1992).

Irrigation also altered the land by allowing farmers to plant corn where it would not have been able to grow otherwise; by the 1970s irrigated corn had begun to replace dry-land grain sorghum in parts of western Kansas (Hurt 1986). While in 1939 only 83,000 acres (.2%) in Kansas were under irrigation, approximately 1.9 million Kansas acres (4%) were being irrigated in 1974. Likewise, in Nebraska, irrigation increased from 475,000 acres (1%) in 1939 to 3.9 million acres (8%) in 1974 (USDA 1977). Irrigation was also partly responsible for the rapid growth in farm size between 1940 and the 1980s (Opie 1992).

Fertilizer The use of commercial fertilizer likewise helped minimize declines in production during drought years. While in 1935 farmers used only 6.2 million short tons of fertilizer, by 1970 farmers were using an average of 39.5 short tons of fertilizer (USBC 1975).

Farm Size By the 1970s, there were considerably fewer tenant farmers in the Great Plains, and farms were also larger than in the 1930s. By 1974, 58% of all farms were over 1,000 acres, compared to only 28% in the 1930s (de Janvry and Vandeman 1987). Large farms tend more efficient[7] than small farms and consequently better able to withstand the financial hardship associated with drought.

Migration Farm transfers during this drought were fairly infrequent, and few people migrated from the drought-stricken area. Farm foreclosures and bankruptcies in the southern Plains states did

[7] The 1974 Census of Agriculture estimates that small farms consume four times as much energy per unit of output than do larger farms (Tweeten 1987).

increase moderately, however, during the mid-1970s (Table 1.1). Whereas between 1968-1974 foreclosures averaged .73% per year, in 1976 2.4% of farms were foreclosed due mostly to farmer debt (USDA 1977).

The Federal Response to Drought - 1930s

Although there had been several droughts in the Great Plains region during the 1800s and early 1900s, a strong national tradition of laissez-faire capitalism prevented the federal and state governments from intervening on behalf of farmers. Thus, until the drought of the 1930s, few formal programs existed in the United States to administer food relief or other assistance to citizens under stress. The Great Depression brought with it changes in attitude about government intervention in the free-enterprise system. It also brought about the creation of a vast network of programs designed to help millions of people survive the combined effects of drought and economic depression.

The first major piece of legislation to address agricultural problems was the Drought Relief Act, signed by President Hoover in 1930. The Act provided loans for seed, feed, fuel, and fertilizer; in 1931 these loans amounted to $56 million (Porter 1989). This is approximately .07% of the of the 1931 GNP (USBC 1975). Because the terms of the loan required prompt repayment, however, many farmers were unable to meet their obligations and fell deeply into debt. This was one of the reasons they voted overwhelmingly for Franklin Roosevelt in the 1932 election.

FDR initiated a more comprehensive national program of drought relief. A series of organizations was established to help deal with the problem of drought. One of the most important agencies was the Agricultural Adjustment Administration (AAA), created in 1933. The AAA program had two major phases: the first was to offer payments to farmers who reduced production of certain commodities in an effort to bring up prices. The second phase encouraged soil conservation by paying farmers not to plant soil-depleting crops, such as corn and wheat, but to plant instead soil-conserving crops, such as grasses and legumes (Hurt 1981). Later the AAA also began to purchase submarginal land in order to restore it. Nearly all Dust Bowl farmers participated in AAA programs, and AAA payments become the primary source of income for many farmers between 1933 and 1937 (Hurt 1981).

Another New Deal agency set up to assist farmers was the Federal Emergency Relief Administration (FERA), which became the Works Progress Administration (WPA) after 1935. This organization provided funding for soil conservation operations as well as assistance to farmers for the purchase of feed, seed, fuel, and other necessities. In 1934 FERA paid more than $53 million to purchase marginal land to retire it from agricultural use (Dyson 1988). FERA also offered relief payments to up to 90% of the population in eastern Oklahoma counties in 1934 (Gregory 1989). Indeed, for many farmers in the hardest-hit parts of the Great Plains region, FERA meant the difference between staying on the farm and migrating (Hurt 1986).

The Resettlement Administration (RA), created in 1935, offered loans to the poorest farmers who could not obtain credit elsewhere. The loans were to be used to purchase seed, feed, fertilizer, food, and clothing and to encourage crop diversification. The RA also spearheaded a program to purchase cropland to restore it to grassland. The federal government purchased small, uneconomic farms,

relocating the owners to specially-created agricultural communities, where they would be given small plots of land (25-100 acres) to farm. Some displaced farmers moved into towns or left the region altogether.

One of the most important relief agencies during this time was the Soil Conservation Service (SCS), a grassroots organization which helped develop soil conservation districts around the Great Plains, educating farmers on how to prevent soil erosion through proper tillage and cropping procedures (Hurt 1986). In 1936 the SCS published a model state law that would enable local farmers to establish their own soil conservation districts by local petition and referendum. Several states passed their own version of this law the following year. Farmers living within the self-determined boundaries combined efforts to prevent further soil erosion and misuse of the land. The program demonstrated that it was possible to revitalize the soil through replanting and controlled grazing, and by mid-1939, there were 37 soil conservation districts encompassing over 19 million acres of land (Hurt 1981).

The Agriculture Department's Forest Service also took part in soil conservation efforts. The Service sponsored a large shelterbelt project which was responsible for planting nearly 18,600 miles of shelterbelts with more than 217 million trees over an eight-year period (Hurt 1981). Trees were planted along a narrow, 100-mile-wide zone parallel to the 99th meridian, which was the transition between the tallgrass prairie and the shortgrass plains. The zone extended from northern Texas to the North Dakota/Canada border (Worster 1979). The belts averaged between one-half and one mile long and were 132 feet wide. Within each belt, up to a dozen species of trees were planted, the fastest growing trees at the center, with smaller shrubs along the outside (Hurt 1981). The trees provided a stop for blowing soil and helped reduce evaporation in the sheltered areas (Hurt 1981). In addition, the $14 million shelterbelt project also provided work for thousands of unemployed residents of the Great Plains.

State and local advisory committees likewise became involved in drought relief activities. These bodies made recommendations to Washington agencies regarding drought relief eligibility. In 1934, for example, the states designated as drought-stricken 1,457 counties in every state west of the Mississipi except for Washington, plus Illinois, Indiana, Wisconsin, and Michigan. Once a county was registered on the disaster list, it became eligible for aid from a variety of federal programs, including direct work relief, livestock purchase, seed and feed loans or grants, conservation measures, modification of AAA contracts, and railroad reduction rates (Dyson 1988).

In the spring of 1934 President Roosevelt put together a drought committee made up of administrators of the AAA and the FERA, the governor of the Farm Security Administration, and the Secretary of Agriculture. The Committee reported on the drought situation and federal responses until that time. It also recommended to the President that an additional $475 million be appropriated for relief programs.

In June of 1934 the President asked Congress for an appropriation of $525 million for drought relief. This was .81% of the GNP for that year (USBC 1975). The additional $50 million was added to provide employment in work camps for young men in towns and cities. Elements of the drought relief program included

- $125 million for special work programs and human relief
- $75 million for addition to funds available under Jones-Connally Act for livestock purchase
- $100 million for shipping, processing, and distributing purchased cattle
- $100 million for emergency feed purchase, loans, and shipments
- $50 million for emergency purchase of submarginal farms and assistance in relocating farm families.
- $25 million for purchase of seed for the 1935 planting season and for loans to get seed into farmers' hands
- $50 million for employment in work camps for young men from towns and cities (Wilhite and Rosenberg 1984b).

The Federal Response to Drought - 1950s and 1970s

The programs created in the 1930s were the forerunners of programs developed during the course of the next several decades in response to new drought emergencies. As mentioned earlier, drought recurred in the Great Plains in the 1950s. During this time additional government programs were put in place to cushion farmers from the impacts of drought. Between 1953 and 1956 the federal government spent $729 million on both long-term and short-term drought relief programs (Wilhite and Rosenberg 1984a). This represented 1.9% of the average GNP for those years (USBC 1975). By 1954, 869 counties in a 15-state region had been declared drought disaster areas, making them eligible for disaster relief loans. In all, 32 states received drought assistance between 1953 and 1956.

Relief programs during the 1950s consisted of production disaster loans, economic disaster loans, special livestock loans, and programs for emergency feed and hay, soil erosion, and beef purchase (Dyson 1988). The drought programs of the 1950s were coordinated by the Secretary of Agriculture's Drought Committee, which was assisted by state and local committees. Also participating were the Farmers Home Administration (FmHA), the Soil Conservation Service, the Agricultural Extension Service, Agricultural Stabilization and Conservation, and Civil Defense (Dyson 1988).

By the time the drought of the 1970s came along, many government programs were in place to assist farmers (Table 1.2). In the early years of the drought, then-President Gerald Ford wavered on providing federal support. However, additional programs were added beginning in 1977, with the election of Jimmy Carter. Under the Carter Administration a variety of agencies, such as the USDA, the Soil Conservation Service, the Bureau of Land Reclamation, the Farmers Home Administration (FmHA), the Small Business Administration (SBA) and the Department of the Interior, made disaster relief loans and grants available to farmers.

The Presidential drought package of 1977 consisted of $794 million. This was only a small portion of the total federal drought assistance program, however. The overall federal assistance package included nearly 40 distinct programs managed by 16 different agencies. The Departments of Agriculture, Commerce, and Interior alone spent over $5 billion on drought relief programs to water users during 1976-77 (Wilhite and Rosenberg 1984a). The U.S. GNP ranged between 8.1 and 9.0 trillion during those years (USBC 1992).

During the 1970s, traditional loan, feed, and seed programs were supplemented by disaster relief payments, which greatly increased the cost of drought aid (Dyson 1988). Farmers of the 1970s were also eligible for federally subsidized crop insurance, which compensated them for income lost owing to crop failure. However, most farmers were reluctant to enroll in such programs, because various legislative initiatives passed during the decade had made it more convenient to receive disaster relief payments. For example, during the 1970s farmers producing wheat, corn, sorghum, barley, upland cotton, and rice could receive disaster payments authorized under the Agriculture and Consumer Protection Act of 1973, the Rice Production Act of 1975, and the Food and Agriculture Act of 1977, as amended, if climatic conditions prevented planting or reduced crop production below a certain level (Dyson 1988). Thus, between 1974 and 1981, the federal government spent over $3.8 billion on disaster relief, while less than 10% of farmers had crop insurance. In subsequent years, however, legislation was passed aimed at reducing expensive disaster relief programs and encouraging farmers to purchase subsidized insurance (Dyson 1988).

While the U.S. has maintained a large supply of grain in reserve since the 1930s, U.S. reserves were low during the 1970s, which resulted in a rise in wheat prices during that decade. These high prices helped sustain many farmers during the drought years, though consumers paid more for grain products[8]. Public grain stocks can help keep both grain supply and prices relatively constant despite production shortfalls; presently, the U.S. grain reserves comprise one-third to one-half of total global stocks (CAST 1992). It is expected that the grain reserve will help cushion the U.S. against the effects of future droughts.

[8]During the 1930s, prices had been low, owing to overproduction the previous decade.

Summary

The drought of the 1970s was much less catastrophic to society than the drought of the 1930s for several reasons. First, while the drought was extremely severe in certain areas, it was actually much shorter than the decade-long drought of the 1930s. In addition, no economic depression accompanied the drought, as was the case during the 1930s, and fewer Americans were involved in agriculture--4.6% compared to 25%. But more importantly, the many lessons learned during the 1930s made it possible for later farmers to avoid some of the mistakes that had intensified drought damage in the 1930s. These farmers, for example, were more aware of the relationship between farming methods and erosion, and they practiced more environmentally benign farming techniques. In addition, they also had access to more advanced technology, including irrigation, improved fertilizers and pesticides, as well as drought-resistant varieties of seed.

Another major advantage for farmers of the 1970s was stronger backing from the federal government. By the time the 1970s drought struck, a wide variety of government programs had been in place for 40 years. In addition, presidential support for federal loan programs, crop subsidies, price supports, disaster relief programs, research programs, and county extension services all contributed to the ability of the agricultural system to survive the drought of the 1970s.

In addition, more readily available bank credit and the overall capital-intensive nature of modern farming meant that fewer American farmers would be forced off their land during droughts[9]. In general, the larger the farm, the more efficient it is and the better able it is to withstand financial hardships associated with drought. Indeed, true farm abandonment and large-scale migration, like that which occurred in the Great Plains in the 1930s, was very rare during the 1970s. The most common reason for farmers to leave their land in the latter half of the twentieth century had less to do with drought and more to do with everyday economics, e.g., debt, low farm prices, and the difficulties family farms have competing with more capitalized operations.

[9]Those farmers who did leave because of drought tended to be small-scale farmers or farmers who had only been in business two to three years prior to the onset of drought and had thus not accumulated sufficient capital reserves to sustain themselves during hard times.

PART II - MEXICO

Potential Impacts of Drought on Mexico

As stated earlier, our hypothesis is that the American Dust Bowl experience may be regarded as an analog for possible future climate conditions and human responses in the northern hemisphere mid-continent region such as Mexico. Mexico historically suffers drought in at least one state every year and suffers regional drought at least three years of every decade. General circulation models predict that future warming will be greater than it was in the 1930s and Mexico risks more severe climatic consequences than did the Dust Bowl (Rosenzweig and Hillel 1993; Liverman 1990; Liverman 1992a; Liverman 1992c).

Our analysis of the droughts in the Great Plains of the United States and studies by other researchers show that response to drought depends not only upon climate but also upon a number of environmental and social variables, including the geography and ecology of an area, agricultural practices, social structure, land tenure, politics, and economics (Liverman 1990; Liverman 1992a). With respect to response shifts in the U.S. drought in the 1970s in comparison to the 1930s drought, 1) severity of the drought, 2) economics, 3) government programs, 4) environmental factors, and 5) agricultural technologies and practices all played a role in preventing migration and alleviating severity of the drought. In order to understand what the response to drought is now, and what the options for are Mexico in the future under a global climate change scenario, we must also compare and contrast these same variables in Mexico to those which resulted in farm foreclosures and migration during droughts in the United States.

The proximity of Mexico to the United States has provided an opportunity for migration for many Mexicans in the past century. If CO_2 concentrations double to create proposed conditions of global climate change, Mexico may suffer an increased frequency of droughts similar to those of the Dust Bowl years. If there are other similarities between the situation in Mexico and that of the Dust Bowl based on the indicator factors developed in Part I, then increased migration to the United States as a result of the impact of global climate change is a very likely response.

Geography and Weather/Climate

Physiology and climate of a region drive its ecology to a large extent, since vegetation depends upon soil types and local climate. Mexico contains two mountain chains, the Sierra Madre Occidental and Oriental, and a southern extension of both called Sierra Madre del Sur and two coastlines. These form a series of highland basins surrounded by high mountains, rangeland, and desert as well as coastal plains (FAS 1992). Mexico is subject to tsunamis along its Pacific coast, earthquakes in its center and south, and severe hurricanes on its Gulf coast (Commerce 1993; Wellhausen 1976).

The total land area of Mexico is 495 million acres, approximately three times the size of Texas (Commerce 1993; Fernandez 1986). Although 75-80 million acres are considered potentially arable, some of that land is in low-lying tropical areas that are poorly drained, whose introduction to agriculture would require large investments (Wellhausen 1976; EIU 1993). Based on the ecological and hydrological properties of tropical rainforests and wetlands, utilizing the low-lying tropical areas for agriculture is scientifically inadvisable. Only about 42.5 million acres are under cultivation in

Mexico, about as much as is cultivated in the state of Iowa alone (Fernandez 1986; Wellhausen 1976).

Wheat, sorghum, oilseeds, cotton, sugarcane, vegetables, and forage are grown in the northern states through irrigation. Livestock are also supported in the northern rangeland and plains of the Gulf states. The irrigated areas of the central states support wheat, oilseeds, feed grains, vegetables; the nonirrigated regions support corn, beans, and other subsistence crops and subsistence livestock farming. The tropical south supports citrus, coffee, rice, sugarcane, bananas, cocoa, pineapples, and vegetables for export.

Average rainfall in Mexico is 700 mm (28 inches), but it is unevenly distributed as a result of the geography (EIU 1993). Average temperature is 20 degrees C in the lowlands (Livierman 1992c). The westerlies bring the rainy season from the Pacific Ocean in the summer, but the Sierra Madres cause a rain shadow effect producing arid-scrubland to desert conditions on the eastern side of both chains. The rainy season is often interrupted by dry periods called caniculas. As a result, the northeastern coastal plain and north central plateau states have an arid to very arid climate with average annual rainfall of 500 mm (20") with a less frequent maximum of 800 mm (34") and a more frequent minimum of 100 mm (4") (Conteras and Cifuentes 1986; Liverman and O'Brian 1991). In comparison, the Great Plains receive an average of 30 inches of precipitation a year. The central states of Mexico have a semiarid to dry tropic climate with average annual rainfall of 850 mm (34") with a maximum of 1200 mm (50"). The northern and central states have suffer drought during at least one of three years of every decade included in the climate record (EIU 1993; Metcalfe, 1987; Cross, 1981). By contrast, southern Mexico contains a region of tropical rainforest which receives over 1200 mm (50") of rain annually (Commerce 1993; Contreras and Cifuentes 1986).

Droughts have historically been most frequent in the northern states (Table 2.1) (Acosta, Ohmstede, and Zevallos 1993). In this century, severe droughts occurred in the northern states in 1935, 1944-46, 1957, 1960, 1962, 1969, 1970, 1974-75, 1978-79, 1982-83, 1988, and 1989 and in the central states also in 1944-46, 1949-50, 1974-75, 1986-87, 1988, 1989 (Metcalfe 1987). In the 1989 drought, communities in northern Mexico rationed water or were without water completely (Liverman 1992c). Children died from dehydration.

Global Climate Change Predictions

Five general circulation models (GCMs) have been tested using data from Mexico and compared to current conditions to determine future climate condition (Table 2.2) (Liverman 1992b; Liverman and O'Brian 1991). Although there is variation and sizeable uncertainty across the models as to the extent, these models forecast higher temperatures and changes in patterns of precipitation in Mexico as a result of climate change. Sea level rise of up to 1 m, another possible result of global climate change, and would affect Mexico, as it would all other regions (USEPA 1989). In a country not only with an arid climate which historically suffers frequent, severe droughts, but with an agricultural region bordered by the ocean which could suffer salt water intrusion into the water table, and a high rate of population growth these impacts of global climate change could be detrimental to agriculture and the economy (Liverman 1992b; Liverman and O'Brian, 1991; Metcalfe 1987). Indeed, severe droughts and floods are thought to have caused the decline of numerous Mexican civilizations

(Metcalfe 1987). If rainfall decreases and temperatures rise, increased evapotranspiration rates, salt water intrusion in low-lying areas, soil salinization, and, possibly an increase of agricultural pests may result. If rainfall increases significantly, leaching of already nutrient poor soil, extreme erosion, salt water intrusion, increased pests, and flooding could result.

All of the GCMs applied to Mexico predicted increases in mean temperature (Table 2.3) (Liverman 1992b;Liverman and O'Brian 1991). The topography of Mexico causes much of the uncertainty of these GCMs, since rain shadow and elevation are not taken into account. In general, regional estimates are more useful than country-wide estimates for studying the effects of global climate change as Table 2.1 shows, even droughts are very localized. This a particular problem in developing estimates for the impact on Mexico, since it can be divided into several regions based on topography. Higher temperatures may benefit the agricultural regions at higher elevations or lengthen the growing season. However, increased evaporation rates as a result of the increased temperatures may counteract possible increased precipitation (Table 2.4) (Liverman 1992b; Liverman and O'Brian 1991). Drought results from a combination of reduced precipitation and an increase in the climatically imposed atmospheric demand for water by temperature (reduced soil moisture through evaporation). In determining the impact of such drought or flood intensity and frequency as predicted by GCMs, it is necessary to understand Mexican agriculture, economy, and social structure; for, as discussed earlier in the comparison between the impact of severe drought on the U.S. farmers in the 1930s and in the 1970s, given the proper structuring, these elements can withstand the impact of severe natural hazards.

Agriculture

Agricultural History

Historians say that the past defines the future and that is indeed true in Mexico. The Spanish colonization of Mexico led to the hacienda system - a system similar in some ways to the plantations of the United States South and in other ways similar to the agriculture dependant on migrant help in California, Washington, Texas, Florida, etc. today - in which wealthy landowners held large amounts of land that was farmed by peasants and slaves. Cooperatively owned farms called *ejidos*, typically divided into plots farmed by individual families, communally owned farms called *communeros*, or small family plots made up the rest of agriculture. The Mexican Revolution and adoption of agrarian reform in the Constitution of 1917 promised the breakup of the hacienda system; however, in many regions, it was not until the more progressive wing of the ruling party, led by Lazaro Cardenas, implemented agrarian reform in 1935, that many haciendas were broken up to provide parcels of land for peasants who formerly had worked on the haciendas and to create *ejidos* (Keen 1991). Land reform continued until it was officially concluded in 1992 (EIU 1993). The utility of such small parcels of land and their subsequent division into *parcelas* for subsequent generations was not considered during in the reform process. As it turned out, the land reform contributed to unemployment, increased subsistence farming, high susceptibility to drought, and migration as will be discussed later. Today, a little more than 50% of arable land is owned by *ejidos* (Liverman 1992a). The hacienda system was not abolished completely, however, but continued as a new system of

investor ownership of large landholdings called *neo-latifundios* more similar to the modern American large scale farms and agribusinesses (Keen 1991; Wionczek 1982).

The agrarian policy of President Cardenas encouraged the irrigation of *ejido* land and by 1940 some 800,000 hectares (60%) of the *ejido* landholdings at that time were irrigated (Wionczek 1982). Later Mexican presidents during the 1940s and 50s dedicated more than 10% of the federal budget to irrigation projects in the modernization process; however, these projects were concentrated principally in the regions along the Pacific Coast, and the Colorado River and Rio Grande basin area where latifundios dominated and return on investment would be highest. Lack of credit prevented small landholders from obtaining and maintaining irrigation systems (Woinczek 1982). At the same time large portions of the fertile *ejido* land irrigated in the 1940s were rented or purchased by investors - *latifundistas* - unofficially or through government officials, for commercial, particularly export, production in the 1960's allowing or forcing people to migrate elsewhere (Keen 1991; Liverman 1990;Liverman 1992a).

The technological advances in Mexican agriculture began with use of domestically produced chemical fertilizer and included the Green Revolution promotion of high yield hybrid cultivars, pesticides, and mechanization. These advances initiated a major expansion of production of staples as well as export crops through 1940s to the 1960s and allowed Mexico not only to be self-sufficient, but also to export crops through the early 1960s (Cross 1981). Agricultural production grew as a result of nitrogen inputs alone by over 200% (Wellhausen 1976). Such modernization was restricted by cost and the credit structure to the wealthier farmers and large landholders.

Although maize production benefitted greatly from the new technologies, wheat benefitted the most, since the U.S. technical package adapted to Mexico was developed for U.S. style agriculture - areas of 1000 acres or more of level irrigated land. The farmers growing wheat were more affluent (maize is a staple crop). The average *ejido* parcel of 12 acres per owner/family is not economical for growing wheat. *Campesinos* typically could not afford the fertilizer, machinery, hybrid seeds, and pesticides to compete in commercial production and were left behind as agriculture in Mexico modernized. Some *ejiditarios* did put their land together into "irrigation districts," allowing both irrigation and use of machinery and therefore commercial production (Yates 1981). Economics and climate combined, as will be discussed later in this paper, encouraged many to seek out the cities of Mexico or to become seasonal agricultural laborers in the United States through the Bracero Program (Cross 1981). The Bracero Program admitted Mexican agricultural laborers to work legally for a short period on a U.S. farm.

Modern techniques made agriculture a business rather than a status symbol or means of subsistence. The swift acceptance of new farming techniques and new crops in the northern export-oriented states may have been due to the fact that these farmers had already broken with tradition to migrate to the northern border states in search of employment on the *latifundios* and on newly designated *ejido* land (Cross 1981).

Agricultural production of domestic food crops continued to decrease with respect to demand through the late 1960s and 1970s (Table 2.5). The primary causes of the decline were declining world prices for the crops, population growth, shifting of investment into Mexican industry, and decreasing involvement by the government in semi-commercial or subsistence agriculture. Oilseed and feed

grain provided higher profits for the latifundios and commercial and semi-commercial farms than could be gained from production of maize and wheat for domestic use. As more people moved into the cities, demand for meat caused an increase in livestock production. Pasturage for livestock alone was extended to meet the demand for meat where the land may have been utilized more effectively by conducting mixed farming of crops and cattle (Fernandez 1986). At the same time, Mexico was becoming increasingly dependent on imports for basic grains (Thompson and Hillman 1989; Fernandez 1986). In such a situation, severe droughts were able to affect agricultural production and, thus, the economy.

The gap between modern commercial and subsistence-level agriculture continued to increase in the 1970s. The Mexican government did intervene to increase public credit and subsidies, yet these were linked to purchase of fertilizers and other technologies and thus failed to benefit the *campesinos* who needed credit and subsidies most (Appendini and Liverman 1993). At the same time, climatic conditions were unfavorable and reduced the crop harvested in the rainfed areas particularly. Such economic and climatic conditions placed pressure on small scale commercial and subsistence farmers and encouraged them to sell their land or leave it to relatives and move to urban areas.

The combination of the events discussed above caused insufficient basic food grain production, resulting in inadequate diets for millions of Mexicans, and a need for grain imports and U.S. dollars through the 70's (Contreras and Bassoco 1986; Thompson and Hillman 1989). In response, the Mexican government initiated the Sistema Alimentario Mexicano (SAM) or Mexican Food System, in 1980 to return Mexico to self-sufficiency in staple food grain production. The SAM program achieved solid, but short-lived results. However, when the price of oil collapsed in 1982, the Mexican government lacked the revenues to sustain the SAM program (Thompson and Hillman 1989). Production levels tapered off as Mexico encountered droughts again in the late 1980s and as government funding was cut for agricultural support.

Water/Resources

Land tenure

Land tenure has been a major issue in Mexican politics since the beginning of this century. Today, over 25% of the Mexican work force is in agriculture, just as in the United States in the 1930s (Commerce 1993). Of the approximately 2.8 million farm units in Mexico in 1976, 7.1% were modern, using improved technologies for agriculture; 40.5% were semi-commercial, using some of the modern technologies; and 52.4% of farms were subsistence level (Wellhausen 1976). This proportion is likely to be similar today, given that the proportion of *ejido* land remains the same and there have been no significant shifts in agricultural production since the 1960s. Modern farms in the north and central states of Mexico may be up to 750 acres if the farm includes cattle ranching (one owner) or much larger if multiple landowners choose to invest together as *latifundistas* (Yates 1981). Plantation agriculture, financed by Mexican and multinational agribusinesses and *latifundistas*, is common throughout the south and coastal states and produces coffee, sugar, rice, and tropical fruits. Private semi-commercial farms owned by the *pequenos propitarios* (those who own only up to the legal amount of land) tend to range from 50-150 acres in the northwestern irrigation districts, 30 to 40 acres in the central states (Yates 1981). The official legal maximum for land holdings is 250 acres per owner, but because of inheritance issues, farms are often fragmented. As a contrast, the average

size of land held by a family farmer during the 1930s in the U.S. was 320 acres, an amount which was basically unsustainable during the severe 1930s drought. Almost 50 percent of Mexican agriculture is currently on ejidal land (FAS 1992). Each *ejido* farmer (*ejidatario*) was initially granted 12-15 acres. Some *ejiditarios* work together to arrange irrigation districts and enable use of machinery. Others work independently and still others rent their land (illegal until 1993) to other, typically private, landowners (Yates 1981). In the south and Gulf states, private farmers with as little as 5 acres may put that land into contracted production for agribusinesses.

Water and soil resources

If global climate change would mean a reduction in precipitation for some regions of Mexico, the problem will be serious. Already, water is an increasingly limiting resource for Mexican agriculture. Natural water resources are scarce and polluted in the North, and inaccessible and of poor quality in the center and extreme southeast (Commerce 1993). In addition, during every year in Mexico's recorded history one area or another has experienced drought or devastating floods (EIU 1993). One difference between the Dust Bowl and Mexico is that the large farms in Mexico are already using irrigation and thus are somewhat more protected; however, only 20% of arable land is irrigated and the majority of water sources are already utilized (FAS 1992). As two-thirds of the country is arid or semi-arid and experiences "erratic" precipitation, yields will continue to be affected. Irrigation has also led to a lowering of the groundwater tables, and the dry weather of the past two decades has led to serious water shortages (Wellhausen 1976; Liverman, 1990b; Liverman and O'Brian 1991; Liverman 1992a; Liverman 1992c; Wionczek, 1982). Intrusion by salt is a major issue confronting the coastal states as groundwater is depleted and the potential for sea level rise of one meter. Importantly, the coastal states Baja California, Sonora, and Sinaloa are the main agricultural regions producing export-oriented crops.

Many irrigation districts depend on small reservoirs and wells which are depleted quickly in very dry conditions (Yates 1981). The distribution of crops and agriculture does not coincide with the availability of water resources. Only 12 percent of the available water is found in the central highlands in which 51 percent of the cropland and 60 percent of the total population of Mexico are found (Liverman and O'Brian 1991). Only 8.5 million acres of 42.5 million acres in the central highland states of Mexico are irrigated; this area represents more than one-half of the value of Mexico's potential agricultural production, including both domestic and export crops (Wellhausen 1976; Contreras and Bassoco 1986). The remaining land in the central highlands where domestic crops and particularly subsistence farming is practiced depends on rainfall and where there is production of cash crops, there is some irrigation with surface water. Agriculture currently consumes 80 percent of the available water; the most productive cash-crop oriented agricultural region is in the highly irrigated yet highly drought prone states of the northwestern coastal plain (Sonora and Sinaloa), and the arid central plateau states of Coahuila and Chihuahua (Wellhausen 1976; Liverman 1990a). Mexican industry, U.S. industry, and U.S. agriculture compete with Mexican agriculture for water in the export crop-oriented northern border states (Yates 1981; Sanderson 1989). When drought occurs, priority for water shifts to export crops (Table 2.6) (Mares 1986).

Up to 50% of the cultivable land in Mexico may be idle each year. Reasons include lack of rain, lack of irrigation water, lack of credit, marginality of the land, lend-tenure disputes and the traditional slash-and-burn farming system (Fernandez 1986).

Soil erosion is another major problem facing agriculture since 61% of the arable land in the rainfed districts is located on slopes of a 4% grade, and soil conservation methods in Mexico are unknown. Loss of water through inefficient irrigation systems, leakage from reservoirs, and seepage from canals are major problems (Yates 1981). Losses from "efficient" irrigation systems may reach 40% of the original quantity of water passing through the system and from inefficient systems, 75%. Given a scenario of frequent drought conditions in combination with salinization of the irrigated soils and the needs of a large population and industry, these losses are critical.

Modernization and Green Revolution practices make little use of traditional insights and techniques, and displace the native open-pollinated varieties of grain that help reduce the impact of pests which may be associated with drought. The use of a few inbred varieties which generate infertile seeds reduces genetic diversity. The reduction of diversity has in Mexico increased the risk of failure in response to natural hazards (Liverman 1992a). Tolerance to disease and pests inherent in the native varieties may be lost. Lack of access to credit to purchase drought-resistant cultivars does put poor farmers at a disadvantage. Higher expenditures on improved, drought-resistant seeds has been determined to result in somewhat lower drought losses (Liverman 1990b). Traditional farming practices intercrop maize and bean, and maize and squash. These practices are ecologically sound and provide some defense against pests and provide soil moisture conservation as well (Andow and Rosset 1990; Liverman 1992c). However, the credit, insurance, and fertilizer programs are not available for this kind of cropping (Fernandez 1986). Instead, these programs are designed to favor monoculture of export crops despite the fact that productivity is higher in polycultures while monocultures attract pests and thus require expensive inputs of pesticides (Vandermeer 1990).

More than 90% of natural hazard losses in Mexican agriculture are from drought (Liverman 1992a). Other natural hazards include flooding and frost (Liverman 1992c; Fernandez 1986). In 1970, a drought year, 19% of all the planted land in Mexico was not harvested and 50% of the sown area in the central and northern states was abandoned. In comparison, as discussed in Part I, during the 1930s in the Great Plains 30% of crops sown were not harvested. Again, in 1982-83, when rainfall in Oaxaca was 30% below normal, maize yields were 75% below normal. Even in a year like 1990 with overall favorable weather, 7% of the crop area was not harvested because of regional drought (Appendini and Liverman 1993). Given the predicted scenario of reduced precipitation and increased evaporation with a doubling of CO_2, such bad years could become more frequent. Although increased temperatures could reduce crop losses due to frost, those losses due to drought are more significant. Although much of the agricultural land in production in the export-oriented northern states is irrigated, there already are water shortages particularly during the dry season. In addition, although an area may be heavily irrigated, if irrigation is inefficient, losses may still be high. Although 20% of the land in San Luis Potosi is irrigated drought losses may reach 50% (Liverman 1990b). Drought losses on ejidal land are historically greater than the losses on private land (Table 2.7). (Liverman 1990b). Without adequate preparation, the effects of global climate change forecast by the GCMs could devastate Mexico.

Government Programs/Economics

As discussed in part I, the Great Depression of the 30's was a major factor which, in combination with the severe drought, affected the farmers of the U.S. Great Plains economically and socially, leading to farm foreclosures and migration out of the region, to cities and other regions. Similarly, economic factors also drive Mexicans to migrate.

Mexico has one of the largest foreign debts of all the Latin American countries. Agriculture today contributes only 6%-9% of GDP, a result of increasing investment in industry. Underemployment in agriculture is another factor which hurts Mexico's economy (FAS 1992). Mexico incurred its national debt during the 1970s by taking on large loans when its production of crude petroleum was highly profitable. The majority of the Mexican foreign debt is owed to U.S banks, and Mexico is extremely dependant on its agricultural production as a means to pay off the debt. Mexico is a major exporter of agricultural goods; indeed, Mexico is the United States' second largest source of agricultural goods. However, it is also the third largest importer of U.S. agricultural commodities (Commerce 1993). In 1990, Mexico's imports from U.S. totalled $9.3 billion and sales totalled 2.8 billion (FAS 1990). The national economy is not an institution unto itself, however, and clearly the social structure of Mexico also impacts the economy and potential responses to climate change.

Social Structure

One of the major differences between the ability of Mexico and the United States of the 1930s to deal with the welfare of its people is the amount of available land. Mexico today has a population of 85 million (Commerce 1993). However, at a 2.2% rate of population growth, by 2010, 113-123 million and by 2075, an estimated 250 million people, will all need to be fed from an agricultural land base the size of Iowa (Wellhausen 1976; Cross 1981; Ginzberg 1991; CSA 1991). Approximately three-quarters of the population is urban and 50% of the total population lives in poverty (EIU 1993). Population pressure on agricultural areas is relieved through outmigration to urban areas and the U.S. (Cross 1981). At least 20% of Mexicans have inadequate diets and 21% of children under the age of 5 are malnourished (EIU 1993; Winder and Eade 1986; Luiselle 1986). The causes for this situation include a shift to a diet of cheap, processed foods and "American foods" (U.S. basics - wheat, sugar, "snack foods"); focus on export-oriented crops and insufficient domestic production of basic food grains; decline of wages; and inflation.

The labor force is 26 million and the official unemployment rate is 15-18%. However, since agriculture accounts for 25% of those who are officially employed, the number is somewhat inflated (Commerce 1993; Yates 1981). Farming is seasonal, and at peak harvest labor requirements may reach 10 million. Whole families, including children will work during the harvest. In the off-season, those employed in farming may be only 3 million. Of those, many have supplemental income.

Somewhat similar to U.S. President Roosevelt's Depression-era programs, between 1980-82 the government program, Sistema Alimentario Mexicano (SAM) or Mexican Food System, was established to return Mexico to self-sufficiency in staple food grain production. State governors were the principal agents responsible for coordinating SAM programs in their jurisdictions. SAM focussed on the production, marketing, distribution, and consumption of food produced. Public funding of

subsidies to costs, prices, and marketing for peasants and farmers as well as subsidies for consumers did result in a major increase of maize production.

Other SAM strategies included agricultural extension services and risk-sharing. The Trust for Shared Risk (FIRCO) provided government insurance of 100% of production costs with the enactment of the 1980 Law of Campesino Agricultural and Life Insurance (Contereras and Bassoco 1986). Insurance premium subsidies were increased to 97 percent, and a total of 5.5 million acres were covered by insurance in 1982. Insurance coverage began at the time of soil preparation, and the acres of crop planted were insured in the event of natural disasters. FIRCO reduced the price of seeds, pesticides, interest rates for loans, and insurance premiums. The beneficiaries of these programs were the *ejidatarios*, *communeros*, and *pequenos propietarios* (private owners whose holdings do not exceed the limit established by law). Producers of maize and beans in the rainfed areas who were clients of the public banking system received additional support, including subsidized inputs such as mechanization and a guaranteed income for those who adopted the new technologies. The government required the beneficiaries to insure their crops with the National Agricultural Insurance Agency (ANAGSA).

The SAM program achieved solid, but short-lived results. SAM was calculated as accounting for 61% of the 1980 production increase and 75% of the 1981 production increase over the historical production trend in the rainfed areas. In addition, a measurable redistribution of income was attributable to SAM programs. There was, however, no emphasis on soil conservation measures to compensate for the emphasis on mechanization which, as discussed in Part I, contributes to soil erosion and soil degradation, hindering the ability of crops to withstand drought conditions. Production levels tapered off as Mexico encountered droughts again in the late 1980s and as government funding was cut for agricultural support. At the same time, migration to the United States increased.

Since the end of the SAM program, in their attempts to reduce the national debt consistent with austerity programs imposed by the International Monetary Fund (IMF), the last two fiscally conservative governments have lowered subsidies on staple food products and reduced government spending on agricultural production. Mexico's current government has decided on four major policy changes which will impact many of those farmers who are potential migrants: 1) reduce credit for small and medium scale peasant producers, 2) privatize input industries (fertilizer, seeds), 3) abolish support prices, and 4) liberalize trade, except for maize and beans (EIU 1993). Recently subsidies for fertilizer, fuel and electricity were eliminated (FAS 1992). However, as discussed earlier, the reverse policies as instituted under SAM in 1980-1982 were successful in meeting other goals of the current administration - reduce imports, improve health, increase grain production to meet domestic requirements, and modernize Mexican agriculture (EIU 1993; Contreras and Bassoco 1986).

As stated earlier subsistence farmers already have difficulties in obtaining credit, and the above policies would indicate that this will remain the case. Thus, subsistence farmers cannot afford the inputs which would make the farm profitable. Since the 1960s, Mexican governments have moved away from public support of *campesinos* and particularly *ejidarios*. The current government is continuing this trend. This policy has been detrimental to the Mexican economy. In an examination of the economic effect of land reform, Nguyen and Salidavar (1979) show that the *ejidal* system of

agriculture provides a higher marginal return on investment than does the private[10] farm system, in contrast to the popular belief that *ejidos* are unprofitable. Each *ejido* has cultivable land which is typically intensively farmed individually or by families. The *ejidos* substitute labor for capital and benefit the economy by reducing rural-urban migration and reducing unemployment. What economic support is given to agriculture by the government typically favors the modern, export-oriented latifundios and agribusinesses. The inability to sustain family farms and collectives in conjunction with bad years due to weather strains individuals economically and, as in the Dust Bowl years, encourages migration.

The distribution of loans to Mexican farmers is, to a large extent, informal, and loans may be obtained from merchants, dealers, shopkeepers, lawyers, moneylenders, or banks (Yates 1981). Although the volume of credit received from banks has been increasing, this credit was only available to private farmers, since ejiditarios could not use their farm as collateral. Most farm credit goes to the northern irrigation districts and cattle ranches, more secure as investments for the private banks. Funds established in Relation to Agriculture (FIRA) is a mechanism through which the Bank of Mexico as well as the World Bank and Inter-American Development Bank lend money. These funds are also oriented towards large scale farmers. The National Rural Credit Bank does provide short-term (one season) credit for "creditworthy" small-scale farmers and ejiditarios. "Creditworthy" means cash-crop oriented farmers, those that do not produce staples for their families. The bank may actually purchase the inputs for the farmer and the farmer then pays back the bank after the harvest. Those farmers who obtain such credit are insured against natural hazards by the National Agricultural Insurance Agency. However, at least 50% of Mexican farmers are considered "never creditworthy" because of high hazard losses, reliance on traditional farming techniques, and their practice of subsistence rather than cash-crop farming.

Economically, migration of Mexicans to the United States may be profitable to the Mexican government because the emigrants are, as Thompson & Hillman (1991) discuss, an export substitute. Migrants send millions of U.S. dollars each year back to their families remaining in Mexico. Further, they reduce the stress on the economy further by being employed, or even unemployed, in the U.S. rather than Mexico and obtaining benefits from the U.S. government and U.S. employers. In one year (June 1975-May 1976) Mexicans in the United States sent an estimated $30.2 million back to their home state of Guanajuato (Cross 1981). Such regional impact only encourages residents of those states to join friends and relatives in the United States.

Underemployment, unemployment, and low wages throughout this century have led to the migration of millions of Mexicans either seasonally or permanently to the United States (Cross 1981). When the economic situation is more favorable, as during the 1950s when maize production rose in response to an increase in guaranteed prices, the number of migrants to the border region who were not part of the Bracero Program decreased (Cross 1981). In the late 60s, when worldwide wheat and maize surpluses caused a decrease in prices and a lack of profits and a further shift of investment into industry, the number of migrants rose once again. And as we see more recently, immigration from Mexico has risen in response to the collapse of the oil prices, onset of severe depression, and the 1982 drought, as can be deduced from the number of apprehensions of illegal immigrants at the

[10]"Private farms" in this comparison are those greater than 12.5 acres in size

border and from information on legal immigration rates (Bean, Edmonston, and Passel 1991). Mexico today seems to be recovering from the economic problems of the 1980s and has experienced a growth in GDP of 3.9% in 1990 (EIU 1993). If this trend continues, it will provide some relief and may reduce migration.

Adverse climatic conditions do impact the Mexican economy, since increased agricultural imports require increased U.S. dollars to pay for them. Government officials have blamed setbacks in agricultural production and the resultant need for imports on the extremely dry weather between 1970 and 1980 (Yates 1981). Certainly the weather was not the only reason; adverse terms of agricultural prices and rising prices of inputs and machinery also impacted profit margins. However, the impact of climatic conditions was significant enough and visible enough to be used as an explanation by the government. Such a response by government officials in the future would be a certain "indicator" of severe drought conditions and point to a need for programs to counteract the effects of drought to be put in place.

Migration

Migration to the United States has occurred since the end of the 19th century and increased through the 70s and early 80s with a brief interruption in the 1930s by the Great Depression (Cross 1981; Bean, Edmonston and Passel 1991). The major factors seem to be economic and demographic. In our examination of the droughts in the 1930s and the 1970s in the United States as a possible analogy for responses to frequent drought conditions as a result of global climate change, migration was a response to severe drought conditions in conjunction with difficult economic situations, inadequate government support, and inappropriate agricultural practices and technologies. During the 1930s, drought in the Great Plains was a result of decreased precipitation by 1% and increased temperatures of 1-4 degrees C. The GCMs used to estimate future climate conditions in Mexico predict an annual temperature increase of 2-5 degrees C and a decrease of between .1 percent and 23 percent in rainfall; even the most conservative estimate would predict an exacerbation of drought in the arid regions of Mexico and other vulnerable areas (Liverman 1992a; Liverman 1992c). In consideration of the historical relationship of drought to migration in the Great Plains as well as the historical migration of Mexicans to the United States, we must understand current trends and patterns of migration in Mexico, both internal and external, if we are to cope with the consequences of global climate change.

This section of the paper will focus on the three main aspects of migration. They include general trends and migratory patterns, type of people migrating, and reasons behind Mexican migration.

General Trends and Migratory Patterns

Historically a specific pattern of migration exists in Mexico. Numerous studies have identified six western and central northern Mexican states as the core source or "sending" regions for internal and cross-border migration: Durango, Guanajuato, Jalisco, Michocan, San Luis Potasi, and Zacatecas (Cross 1981; Mines and de Janvry 1982). These regions encompass the semi-arid highland regions where rainfed agriculture predominates.

In the 1920s, this region contributed about 70% of all Mexican migrants to the U.S. and is still directly responsible for more than 50% (Cross 1981). Migrants travel to the northern border states and then across into the United States, primarily to California and Texas.

Internal Migration

According to Rodolfo Luque[11], from 1965 to 1970 the majority of migration has been into Mexico City. Most of the emigrants came from central Mexico, although the percentage varied from year to year. Emigrants moved to other cities as well as Mexico City, but not in the same proportion. The three cities that attract the largest number of migrants include Mexico City D.F., Guadalajara, and Monterrey. More recently, the urban areas of Mexico have begun to experience an out-migration of people to rural agricultural regions. About 4.4% of the people migrate internally each year. The movement is from the rural south and central states to cities in the center and northern states in search of jobs and better economic opportunities(EIU 1993; Cross 1981). Massive rural migration into the cities, coupled with exponential population growth swelled the cities and urban areas, breaching their carrying capacity. Shortages of housing, electricity, and natural resources began to take a toll. According to Rodolfo Luque, the people of Mexico soon began realizing that the cities, especially Mexico City, were beginning to reach their limits to growth.

The government of Mexico has been trying to reduce the overpopulation of cities by promulgating a deconcentration of population policy. The administration has offered loans to industry to move into the rural areas, reduced the cost of government land in the countryside, and reduced electricity rates in rural areas with the hope that people will move out of the cities and take advantage of the incentives. However, according to Rodolfo Casillas[12], much of the movement out of the urban areas was not to the rural regions of Mexico but to the United States.

External Migration

Mexicans account for 37% of all legal immigration into the United States and more than 90% of all illegal immigration (USBC 1991). Migration into the United States from Mexico has been increasing steadily since 1965, with few pattern changes, and, if global circulation models prove true, then the United States will possibly see an increase in the amount of Mexicans coming across the border.

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[11]Personal communication, Rodolfo Luque, Subdirector de Estudios de Migracion, Consejo Nacional de Poblacion.

[12]Personal communication, Rodolfo Casillas, Faculated Latinoamerica de Ciencias Sociales.

Migration into the United States can be classified into three patterns: those who migrate to the U.S. to live permanently, those who migrate during months of harvest and return home every six months (i.e., temporary migrants), and those who migrate to the U.S. for 20 to 30 years then return to their homes to retire on their earned wages (Durango and Massey 1992).

Emigrant Characteristics

Men outnumber women in external migration nine to one; however, women could soon outnumber men in internal migration. In recent years women have had more success in finding employment on assembly lines, domestic work, and in other industries, thus increasing the number of women migrating into the cities of Mexico. Many of the migrants are farm hands that have been displaced by technology and agricultural modernization (Durang and Massey 1992). Still others are young men and women venturing out for new opportunities. The average age of the migrants ranges from 15 to 35 years. (Mines and de Janvry 1992). Typically the young people of the village are sent out to gain employment and either return in six months or come home years later to retire. Some migrants visit home occasionally to give money to support their families and then return to their jobs.

Reasons Behind Migration

Reasons for migration include adverse climate conditions, agricultural practices, poor water resources and lack of infrastructure, and networks to assist migrants.

Climate

Mexican farmers have been coping with droughts for years, which are the primary devastating climatic variations Mexico experiences. The caniculas exasperate droughts and make farming in those conditions unbearable, unless there is access to irrigation. Some regions have adapted to these caniculas by instituting irrigation and drought resistant crops. Typically, however, these are the wealthy landowners with adequate capital. The arid northern regions and central states historically suffer the most droughts. Empirical evidence does not show a correlation between rain deficits and yield loss in all cases. Instead, inadequate means of coping with drought lead to yield loss.

Agriculture Initiatives and Practices

In the 1930s President Lazaro Cardenas of Mexico enacted a land reform policy known as the Reparto Agrario. This was an enormous land redistribution effort, which has proven to have far reaching effects (Durang and Massey 1992; Keen 1991). Although the concept was to improve the lot of the *campesinos* (rural agriculturalists), the land reform actually transformed relatively efficient, surplus producing agricultural units into small, inefficient plots. One farmer was noted as saying, "Before the Revolution and before we were given land, we lived better. We were fewer in number and we all worked on the haciendas and sugar mills, and we ate well...now, we have land but not enough work" (Cross 1981). Thus the destruction of the hacienda system in the North Center displaced many workers, and the structure of the new order established in the 1930s failed to meet

rural needs and inevitably perpetuated the process of labor displacement and migration that persists to this day.

The agrarian reform purported to discourage migration. In some instances this happened; however, in others, migration was actually bolstered. Many of the campesinos were given land, but were denied loans; they had no capital or credit to invest in farming necessities, or use as collateral. In certain regions agrarian activists prevented campesinos from acquiring ejido lands; consequently, the campesinos were left without work on the dismantled haciendas, and had no land for subsistence agriculture.

During these decades of political upheaval and agricultural reform the U.S. was viewed as the place to turn and find prosperity. However, shortly following the migration of more than 1.5 million Mexicans from 1910 to 1930, the U.S. entered the Great Depression. The depression reverberated southward into Mexico, and caused the world demand for Mexican exports to drop, and also caused a decline in the production of basic commodities that occupied the majority of the rural center increasing instances of unemployment, underemployment, and subsistence agriculture. In addition, due to increased competition for jobs within the U.S., the Dust Bowl, and increasing hostility towards Mexican workers, 400,000 Mexicans, many of them actually naturalized U.S. citizens, were sent back to Mexico. This resulted in a swelling of the rural population. Between 1930 and 1939 96,000 males entered the job market in San Luis Potosi and Zacatecas. During the same period only 36,000 new jobs were created, meaning that as many as 60,000 people joined the ranks of the unemployed in that decade alone. The government began to realize that something had to be done to stimulate agricultural production in order to deal with these increasing problems.

Agricultural Modernization

As discussed earlier, the 1940s and 1950s brought more agricultural reforms, namely agricultural modernization in the form of the Green Revolution. These included the introduction of commercial farming practices, capital intensive production methods, fertilizers, and mechanization to the farms of Mexico. Agricultural modernization displaced farm laborers by rendering their jobs obsolete. It did result in improved farm management and an increase in the amount of land under production. However, in spite of initial improvements, the unequal distribution of these benefits created a larger gap between the *campesinos* and the wealthy landholders. The technology and education of the period went to those already having money and larger farms. Banks and investors looked for safe markets and thus avoided the *campesinos*. In addition, the most dramatic improvements due to the increased technology and new seed strains benefited the wheat growers who predominantly owned the large fields. The owners of small farms in poorly developed areas of Mexico did not receive much access to irrigation, and they could not afford fertilizer, the new hybrid seeds, or a majority of the new farming procedures. Moreover, for the modernization to succeed it had to be instituted into areas with good quality land; most of the poor had poor quality land that was, in addition, over. Thus the people of the six "sending" regions, where maize was the dominant crop, were again left behind technologically.

The land redistribution policies and modernization policies have made the subsistence farmers, mainly the ejidal land farmers, more vulnerable to climatic variations. According to Diana Liverman (1992a), "community studies show that population growth and redistribution [of land] have clearly

increased vulnerability to drought by encouraging the subdivision of land and increasing pressure on land and water resources."

Networking

Agricultural modernization and land reform not only forced people to migrate but created a system that would help subsequent generations migrate into the United States as well. As each major wave of migration took place throughout the last century migratory networks were put into place. These networks are made up of people who help other people cross the border.

Settlement patterns depend in part on the traditions of the villages from which migrants come (Cross 1981). Some are accustomed to illegal migration, others depend on legal entry, and some are mixed. Villages that traditionally are involved in migration to the United States tend to establish networks at one of the large border cities or towns, and, from there, the people are given guidance on methods to cross into the U.S. either as daily laborers or as seasonal migrants or as more long-term undocumented migrants. The establishment and continuation of the core "sending" region can be traced chronologically and in conjunction with the previously mentioned factors.

An arrangement between the two countries was developed to provide the U.S. with Mexican labor; this was followed by a formal agreement reached in 1951. U.S. Public Law 78 served to formally organize the recruitment, placement, and treatment of Mexican nationals as American field laborers within the Bracero program. During the 22 years more than 4.6 million contracts were issued for at least 1 million people. More than 50% of the contracts were allocated to rural residents of the sending states, an area that then accounted for only about 25% of Mexico's rural population. The termination of the program came in 1964 when again U.S. workers feared job displacement and negative economic impacts of the domestic economy from such large numbers of migrants. Migration did not stop after the end of the Bracero program, however; instead, illegal migration rose and continued owing to consistent U.S. demand for cheap agricultural laborers, continued poor conditions in Mexico and adverse climatic conditions.

Networks have not only helped immigrants across the border, but have also elevated the number of people trying to cross the border by essentially making it easier and safer to cross. Richard Mines and Alain de Janvry (1982) conducted a study on the migratory patterns of Las Animas, Mexico, which illustrates the impact of networks on migration. Las Animas is located in the northwestern section of the core sending region of Mexico, and can be used as a reference point for understanding networks and how they undergird migration into the United States from Mexico.

As thousands of people migrated, small communities of migrants formed. For example, between 1960 and 1964 legalized residents founded permanent settler cores in South San Francisco and East Los Angeles. The residents of these cores began to house and job-place immigrants from their home villages. The settler cores in the United States began to grow into a network system, blossoming into a virtual underground railroad for migrants. Essentially, friends or relatives help direct the migrant in the right direction; they give him shelter, aid in job placement, and emotional support to carry on with his journey. In fact, part of the pull of migration into the United States is the networks themselves; they respond to the economic climate of the villages and cities, and provide them with options. Potential migrants feel they have a support system to help them overcome the rigors of the

actual journey and to help them find job placement; therefore, there is a greater propensity to migrate.

The destination of a migrant and the job he is placed in depends heavily on where the networks are based. For example, the destination of a migrant from Las Animas will depend on the destination of past migrants from Las Animas, assuming he is a part of a network system. Similarly, the type of job he obtains will largely depend on the jobs past migrants of that certain network have traditionally obtained. Networks also explain why migration patterns tend to be concentrated geographically. Networks are, essentially, a semi-organized system of helping migrants make their journey successful. The semi-organized structure has allowed U.S. employers to take advantage of the networks. Many migrants are recruited for labor in the U.S. by the networks.

Regardless of current or future population policies, most of the Mexicans who will be potential migrants to the U.S. for the next 15-20 years have already been born. The continuing population growth will only serve to exacerbate the problems that Mexico is already experiencing. Population growth without adequate planning drains the economy and natural resources, and swells the rural and urban centers, causing greater job market competition and, inevitably, migration (Commerce 1993).

Summary

Migration between the United States and Mexico is not caused by any single factor, but several working together over time. For Mexican farm workers the reasons include political turmoil, unequal distribution of wealth and education, lack of opportunity, a demand for cheap labor by the U.S., an increasing population, and a general desire to escape the poverty and desolate conditions that define the life of many Mexicans who live off the land. Coupled with the social factors that influence migration is the dependence on weather for livelihood. Any fluctuation in weather such as droughts or floods could mean devastation for poor agricultural farmers who do not have the technology or education that could serve to protect them from the disastrous effects of such events. Under the predicted global climate change scenarios, Mexico is going to experience drier and hotter conditions that could drive migration to a new level if other factors remain the same. The choice to leave one's family, land, and country is not an easy one and is driven by several factors that are interdependent.

Throughout the 1900s the Mexican agricultural worker has migrated for a number of reasons. In addition to weather and climate, social, political, and economic factors--some of which are similar to the experiences of the Dust Bowl farmers--have been the force behind the great push northward. If these issues are not addressed and the predictions under the global climate change prove true, a new wave of migrants to the cities of Mexico and the U.S. could have great repercussions for both countries.

The agricultural situation and practices in Mexico today bear some similarity to that of the U.S. Great Plains prior to the Dust Bowl: a sizable percentage of small family farms (*ejidos, communaros*, and *peqenos propietares*) are not irrigated and depend entirely on rainfall; mechanization is lacking; families rely on their crops for subsistence as well as commercial enterprise; large scale monocultures are encouraged by the economic situation; there is a tendency to cultivate marginal and high risk land; environmental degradation is increasing in area; soil erosion is worsening; irrigation is limited or inefficient; land salinization forces use of marginal land; and soil conservation methods are absent. In addition, Mexican agriculture already depends on insufficient water resources for irrigation and sizeable chemical inputs to sustain or increase yield, particularly on degraded land. These "indicators" in the analog of the Dust Bowl suggest that Mexican agriculture is highly susceptible to drought, at least as susceptible as the family farmers of the Dust Bowl were.

Other "indicators" of susceptibility to drought and migration comparable to the U.S. Great Depression of the 1930s are the economic problems facing Mexico. As a result of its large debt and austerity programs, inability to produce sufficient domestic basic grains for domestic consumption, need for U.S. dollars for imports, population growth, and social development expenses for the next 50 years (health, education, infrastructure), Mexico's economic situation is depressed. Unemployment is high, and there are currently opportunities in the U.S. for those who want to work. Although, as for those who moved to California in the 1930s, the opportunities for Mexican migrants may not be as rosy as described, migrating to the U.S. is a means of making a living. Just as in the 1930s in the U.S., underinvestment by the Mexican government in the majority of farmers, uninsured crops, lack of credit, undercapitalized farms, lack of infrastructure all contribute to a lower than optimal agricultural productivity and a high rate of losses due to natural hazards such as drought. In such a situation, it is

only natural that farmers move to the cities or to the United States. It also is economically beneficial for Mexico that many of these people migrate seasonally. All of these analogous indicators of high susceptibility to economic losses due to drought as well as increased migration if drought frequency increases point to a need for both Mexico and the United States to make some important policy decisions as we move into the next century and continue to produce the greenhouse gases and ozone-depleting substances which contribute to global climate change.

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