4. CLIMATE AND SOCIETY IN 20TH CENTURY MEXICO

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4.1 Overview

Mexican agriculture has been dramatically transformed through the widespread introduction of "Green Revolution" technologies (such as irrigation, chemical fertilizers, and improved seeds), through land reform, and by land use policies oriented to export crops and grain production. Drought prone Mexico provides an excellent case to study how technological and social changes alter the impact of drought on food and agricultural systems. The goal of this project is to document and understand how relationships between climate and agriculture in Mexico have changed in the last fifty years. The results from this study for several locations will be interpreted in light of the prospects of regional climate change due to global warming.

Meteorological records, agricultural censuses and reports, and the popular press will be used to reconstruct the climate, specifically drought, and agriculture of twentieth century Mexico. Detailed data from six censuses will be used to map patterns of agricultural production and losses, and to relate them to meteorological, technological, and socioeconomic conditions. Statistical analyses will assess: 1) whether climate determines reported drought losses, 2) whether technology buffers the agricultural system against climatic variability, and 3) the differences in drought impacts between land tenure sectors.

This analysis will be complimented by four case studies of vulnerability to drought which will use local records and interviews to try and show how environmental, technological, and social changes may have altered the impacts of climate on local agricultural systems.

In one case study of maize cultivation in the Valley of Oaxaca in southern Mexico, possible responses to potential regional climate change due to global warming will be assessed. This facet of the project will begin with a detailed study of the regional climate including both historical meteorological data and the dynamics of global, regional and local-scale atmospheric circulation, as historically and spatially related to maize yield in the valley. This analysis will be supplemented by a study of other technical, social, ecological and cultural factors involved in maize cultivation. The implications of the results in terms of the vulnerability of the region to potential climate changes will be discussed.

Every ten years since 1930, the agricultural census has reported yields, hazard losses, land tenure, and the use of agricultural technology for more than one thousand local administrative districts called municipios. These data will be used to map patterns of agricultural production and losses, and relate them to meteorological, technological and socioeconomic conditions. The following hypotheses will be examined:

- *The pattern of drought loss and agricultural production is determined by physical geography, especially climate.*
- *Irrigation reduces the impact of drought on agricultural production.*
- *The use of improved seeds and other Green Revolution technologies is associated with higher yields and lower drought losses.*
- *Small and communally-owned (ejido) farms are disproportionately vulnerable to drought.*

4.2 Research Plan

The following specific research activities and analyses will be undertaken:

4.2.1 Compilation and analysis of meteorological records

The pattern and severity of meteorological drought from 1925 to 1985 in Mexico will be documented using meteorological data available in the library of the meteorological observatory in Mexico City. Preliminary visits to this library suggest that fairly good temperature and precipitation records are available for this sixty-year period for most regions of Mexico. It should be noted that most of these data are not computerized and will need to be hand copied from the original weather records. For this reason, most of the climate analysis will be based on monthly data. It is possible that some digital data sets may be available from climate researchers in Mexico, and could be obtained through personal working relationships, particularly at the Universidad Autonoma Nacional de Mexico or in the Oficina de Climatología. Some recent records for Mexican stations are also available in international data sets. Recent climate records, if available in digital form, would be extremely useful in detailing the current situation.

Current and historical data will be organized and mapped using standard computer-based geographic analysis packages (e.g. ARC/INFO & ERDAS). Drought occurrence will be identified through the analysis of precipitation variability, and through the development of drought indices which include temperature and antecedent conditions. Although the Palmer Drought index will probably be used, we plan to discuss alternative indices with Mexican researchers.

This research task should produce a useful climatology of Mexican drought and will be used as input into the analysis of drought impacts and vulnerability. The data set will also provide a basis for longer term research into Mexican climate and climate change and will be made available to other researchers.

4.2.2 Compilation of data on agricultural yields and production

National-level yield and production data have been published for all major crops in Mexico since 1925. We will attempt to obtain desegregated yield data (by state or municipio) for this time period. We will attempt to compile time series of yields, production, and, if possible, reported hazard losses, at the state level, so that we can compare our record of physical drought severity with agricultural conditions. We will focus on major crops, particularly maize and wheat. This information should be available from the archives of the Secretaria de Agricultura in Mexico City. This data will permit an analysis of relationships between drought and agriculture over time in Mexico. We will seek, in particular, evidence of increased yield variability and yield sensitivity to drought using statistical techniques used by Hazell (1984, 1986) and Michaels (1979) - changes in the coefficient of variation or regression coefficients respectively. We will also focus on how agricultural production has responded in severe drought years to see if the response has changed over time. The research task may be constrained by data limitations, and by methodological problems associated with crop-weather analysis such as the assumption of linear technology trends. It may, at a minimum, be possible to construct a few case study data sets from newspapers or agricultural projects. I have had some success in obtaining time series data (1950-1980) on technology and yields in Sonoran irrigation districts and in the valley of Puebla (1960 onwards).

This task will provide a context for the subsequent analysis of the decadal agricultural census, and a general sense of the changing relationships between drought and agricultural production in Mexico. If desegregated and reliable data is available, and if adequate information about technological change (irrigation, improved seeds, fertilizer use) is found, this research

activity will be expanded into a comprehensive statistical analysis of regional relationships between climate, technology, and crop yields in Mexico.

4.2.3 Analysis of decadal agricultural censuses

This research task will use data from the general summaries of the Mexican "Censo Agricultura, Ganadero y Ejidal" for the years 1930, 1940, 1950, 1960, 1970 and 1980. Most of these censuses (not, as yet, 1980) report information on total agricultural losses from natural hazards for each state, and municipio. They also distinguish between losses in the ejido and private sectors, and after 1950, between large private (over 5 hectares) and small private (under 5 hectares) holdings. After 1950, hazard losses are reported by hazard types, including drought, floods, hail, and "plagas" (pests and diseases). Hazard losses are reported in terms of land area planted but not harvested. Hazard related yield declines are not reported in the census, presumably because data on mean yields was not available. In the more recent censuses, detailed information is also provided on the use of various agricultural technologies such as irrigation, fertilizer, improved seeds, and pesticides. It should be noted that the decadal census actually reports on the previous years crop season. Thus, the 1970 census refers to the 1969 growing season.

There are potential problems with the quality of census data in Mexico. Yates (1981) discusses many of the problems with Mexican agricultural data, and suggests techniques for ensuring the comparability of data between different censuses and government agencies. His major doubt seems to lie in the quality of the data for the livestock sector, fallow land, and some of the detailed land tenure information. He and Coll-Hurtado (1982) both suggest the errors in census reporting are generally random rather than systematic, and are not serious enough to merit the total rejection of the census as a source of research data. In a previous study (Liverman 1990), the consistencies between variables reported in different parts of the 1970 census (such as drought loss and yields) increased my confidence in the utility of the information.

The census data will be used to map and analyze the changing pattern of hazard losses in Mexico (focusing on drought in those censuses where drought losses are reported separately). Census data will be transcribed and computerized from state level census reports, available through interlibrary loan in the United States, or in government libraries in Mexico. The municipio level will provide a very detailed scale of analysis. We will note information on reported hazard losses, not only for drought, but also for floods, frosts, pests and hail, as a basis for other possible studies on hazards in Mexican agriculture. Drought losses will be compared, graphically and statistically, to meteorological conditions in the census years to see if reported

drought losses reflect the physical climate conditions. Hazard losses will also be investigated in relation to physical geography (soils, topography), land use, and agricultural technologies. For example, we will examine how hazard losses in municipios growing rain fed maize compare to those in municipios growing irrigated wheat. And we will examine whether municipios with more irrigation seem to suffer lower drought losses. Statistical procedures will include difference of means, correlation, and regression. We will try to identify the relative significance of irrigation, improved seeds, crop type, and fertilizer use in relation to the severity and pattern of reported hazard losses.

Secondly, the differences in hazard losses on farms of different size and tenure will be compared. We will compare the losses on ejidos, large private holdings and small private holdings. Preliminary analysis suggests that the ejido sector is disproportionately vulnerable to drought. We will attempt to explain any differences in terms of the climatology, physical geography, crop mix, and technology of the different groups, and in terms of the political and economic conditions in each sector.

This research task will provide a detailed example of how census data may be used to study the vulnerability of agricultural systems to drought and other meteorological hazards. The data set on hazard losses in Mexican agriculture will provide a basis for further studies and analyses of natural hazard losses and vulnerability.

4.2.4 Local case studies

It is clear from my work in Sonora and Puebla that large scale statistical analysis provides only partial insights into hazard vulnerability. Thus, an important component of this study will be a set of local case histories of drought impacts and vulnerability. These case histories will be compiled using local newspapers and agricultural records, supplemented by interviews with farmers and local officials. We will ask about past droughts and their impacts, and will seek information and opinions on whether social and technological changes have altered hazard vulnerability. Case studies will be selected to represent a range of agricultural systems. One case study will include a region of rain fed maize production on ejidos and small farms in the valley of Puebla, and a second will examine the impacts of drought on irrigated, high input crop production on larger properties in Sonora. Other case studies will be carried out by graduate students and will partly reflect their interests and expertise.

This study will provide analyses of the relationships between climate, agricultural technology, land tenure, and agricultural production in Mexico which should further our

understanding of interactions between social, technological and climatic change in developing countries. The documentation of past relationships between environment and society in Mexico should provide insights into the future human dimensions of climate change the region. It will parallel a project, already underway in collaboration with Mexican scientists, on the impacts of global warming in Mexico. The study will establish a useful data set of information on Mexican agriculture and climate which can be used to investigate a range of other questions and will be the basis of a long-term commitment to the study of Mexican climatology and agricultural development.

4.3 Data Needs

The following summarizes the data requirements for the four points of the research plan described above, and their likely sources:

4.3.1 Climate data

Item: Monthly temperature and precipitation data for all available Mexican weather stations from 1925 through 1985

Expected Sources: Hand written records of the library of the meteorological observatory in Mexico City.
Digital data sets from the Universidad Autonoma Nacional de Mexico.
Global Daily Summary of the Day TD-9618 daily weather from the National Climatic Data Center.

Item: Daily sea-level pressure, 850 millibar geopotential height, temperature and wind direction and 500 millibar geopotential height and temperature for grid points corresponding to Mexico from 1962 through 1985.

Expected Source: National Meteorological Center Compact Disk Grid Point Data Set

Item: Daily meteorological observations for the Cuajimoloyas, Tejocotes, Ixtepeji, Oaxaca de Juarez, Etla, Tlacolula and Ocotlán weather stations in and around the Oaxaca Valley in the State of Oaxaca. These would include temperature, dew point temperature, sky cover, pressure, visibility and wind direction, if available, from 1925 to the present.

Expected Sources: Hand written records of the library of the meteorological observatory in Mexico City.
Digital data sets from the Universidad Autonoma Nacional de Mexico.
Local Oaxaca station archives.

4.3.2 Yield Data

Item: Annual crop yield data, particularly maize, desegregated to the distrito or municipio level for the years 1925 through the present.

Expected Sources: Library of the Secretaria de Agricultura in Mexico City has partial coverage of the country. This will be supplemented with data obtained from local sources in the case study areas.

4.3.3 Agricultural census and mapping data

Item: State and municipio level data on crop losses due to natural hazards (particularly drought)

Information concerning agricultural technology levels: usage levels of fertilizer, irrigation, pesticides and improved varieties for all states.

Expected Sources: Mexican decadal Censo Agricola, Ganadero y Ejidal 1930, 1940, 1950, 1960, 1970 and 1980.

Item: Digitized boundaries of Mexican states and municipios.

Expected Sources: Mexican Database Project, University of California, MexUS, Riverside California.
Digitization of existing base maps.

4.3.4 Local sources

Item: Local-level information for the case study areas on the impacts of drought.

Expected Sources:

Newspaper archives
Local authorities
Interviews
Local agricultural records

4.4 Results of Master Directory Search

As stated earlier in this report, this particular project was chosen as one of the scenarios for our Master Directory evaluation for two reasons. First, it is a clear case of some very useful data being potentially available that would, in the 'usual' circumstance, only be available through a priori knowledge and personal contacts. Second, the research involves the use of a number of culturally-related data variables, in response to NASA's expressed interest in including such data in the Master Directory database.

The Master Directory search was performed from Penn State utilizing a SUN SparcStation. NSSDC's on-line information services were accessed via Internet.

4.4.1 Usefulness of the database contents

In searching the Master Directory database for specific data sets relevant to the items listed above, very few data sets of any type were found for Mexico. In fact, few data sets were listed for land areas outside of the U.S. and Western Europe. The few coverages available were highly generalized global coverages. Only one data set of interest was found. This was the global daily weather summary from NCDC.

Information given in the 'brief' description within the Master Directory database was very inconsistent. Critical information (e.g., data resolution) is often omitted. Some guidelines for entering these elements of information would be useful in promoting uniformity and preventing omissions of important information. Lesser-known acronyms should be defined.

Information on the acquisition of specific data sets was often limited to a contact name and address. More complete information (e.g., available media, cost, date of entry into the MD) would be very helpful, even if such information cannot be kept completely up-to-date. It was because of this lack of more detailed acquisition information that the global daily weather

summary mentioned above is in reality being obtained from a secondary source for use in this project.

4.4.2 Functionality of the user interface

The overall reaction of the participants in this particular project when using the MD to search for relevant data sets was that the menu-driven user interface was fairly intuitive. It required no time to learn, and individual researchers could perform a database search with no assistance after a connection was established to NSSDC's VAX.

Nevertheless, a number of shortcomings in the user interface became quickly apparent and were perceived as making the search process slower and more awkward than necessary:

- *It did not seem possible to use more than one value for a given search parameter (e.g., discipline). This resulted in the retrieval of a much higher proportion of 'uninteresting' data references for any individual search query.*

- *When changing search parameters, the interface forces the user to re-enter all parameters from that point in the menu downward. A SUN-compatible screen-based editing feature or other means of quickly selecting/modifying any combination of menu elements in any order seems to be needed.*

- *A strict, hierarchical navigation of the menus rapidly became obstructive, even for a first-time user.*

- *No capability such as file transfer or report generation is available for electronically saving wanted information.*

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