# Chapter One

# A Vulnerable Society

## Introduction

28 June 1692 was a very wet day in Celaya, Guanajuato. Unusually heavy rains began falling late in the afternoon and continued all through the evening, causing a rapid increase in the level of the River Laja which ran adjacent to the town. Finally, just after 10 o'clock that night, the river burst its banks. The flood caused 'terrible panic among all the inhabitants of the city' and took place when the people of Celaya were at their most vulnerable.

> With the darkness of the night no one knew where the most danger lay and much less how to escape this … men, women and children were desperately shouting and crying … and the turbulent waters invaded everything with impetuous force … no one believed there was any possible escape from this and all began begging for mercy.

Daylight revealed the scale of the devastation. 'The whole city was left like an immense field covered in mud, uprooted trees and branches, rubbish, debris, bodies of all kinds of animals and … all the other remnants of the near destruction.' Volunteers from local communities joined forces with army troops to clear the debris in search of flood victims, some of whom had died trapped in their houses. In total it was estimated that close to three thousand families lost their houses and livelihoods (Zamarroni Arroyo, 1960; Marmolejo, 1967).

But this calamitous event could not have come at a worse time. Repeated droughts in 1690 and 1691, followed by crop blights, had already led to harvest losses across a broad area. Famine and epidemic disease had then gripped this, and other, regions of the country, causing massive life loss, especially among the disenfranchised indigenous population, some of whom were left without access to even the most basic provisions (Orozco y Berra, 1938; Berthe, 1970). The subsistence crisis that followed resulted in social unrest and the emergence of popular uprisings across central Mexico.

Dramatic as this period was, it was in no way unique. Extreme and unusual weather events and natural hazards, including earthquakes and volcanic eruptions, have continually tested the resilience and resourcefulness of Mexican society. Droughts have regularly destabilized agricultural production and have affected food security and social and economic well-being in various parts of the country throughout history and prehistory (Florescano, 1980; Hodell et al., 1995; Conde et al., 1997; Liverman, 1999) and remain a problem today. Successive droughts in the 1930s, 1950s and 1990s, for example, contributed to water scarcity, harvest failure, illness, livestock disease, land abandonment and water conflict in the north of the country (Sandoval, 2003). Catastrophic flood events, some associated with hurricanes, have also killed thousands of people across southern and central Mexico, have left tens of thousands homeless and caused billions of dollars of damage, both directly and through rainfall induced land sliding.[1] In short, over three hundred years after the devastating events of the 1690s, the impacts of climate change still rank among the most significant threats to social and economic well-being and environmental security in Mexico.

Current climate models all indicate that 'it is likely that all land regions will warm in the 21st century' (IPCC, 2007: 850). It is thought that significant potential increases in temperature will be accompanied by changes in precipitation, with the possibility of more frequent and intense extreme weather events (Fraser et al., 2003; Bogardi, 2004; IPCC, 2007). While it should be acknowledged that such changes could bring opportunities for some, they will increase the vulnerability of others, especially those already socially, environmentally or politically marginalized sectors of society (Tompkins and Adger, 2004). In Mexico, where a substantial proportion of the population works in an agricultural system that relies on relatively low and variable rainfall, and whose prosperity is critical to the nation's debt burden economy, such conditions could prove particularly disastrous (Liverman, 1999). It is anticipated that most of central America in fact will warm over the next century in line with global mean warming, but that annual precipitation is likely to decrease (IPCC, 2007: 892). There are fears that higher temperatures and possibly reduced precipitation could increase the competition for water and falling ground water levels which could in turn exacerbate existing tensions over this most vital resource.

Considerable insight into the specific regional social and economic implications of predicted climate changes can be gained by analysing the spatial vulnerability of society, agriculture and other resources to current and predicted variations in temperature and precipitation (Magaña et al., 1997; Liverman, 1999). The way in which human activities and the natural environment have been affected by and have responded to climate changes and weather perturbations in the past, however, provides another invaluable guide to where the most critical vulnerabilities to possible future climate changes may lie. The purpose of this study is to explore the complex interaction between climate and society in historical perspective across Mexico, by investigating the nature and scale of the impacts of climatic variability and unusual and extreme weather events on different agricultural communities in colonial Mexico between 1521 and 1821. Attention focuses on the variety of responses to climate changes and weather events and how these responses varied according to the changing social, political and economic circumstances throughout the colonial period. The degree to which these impacts and responses were a function of differential social and environmental vulnerabilities will be considered.

## Changing Vulnerabilities

Vulnerability can be broadly defined as the potential for loss (Cutter, 1996: 529) or 'the degree to which human and environmental systems are likely to experience harm due to a perturbation or stress' (Luers et al., 2003). Though frequently referred to and widely used in the risk, hazards and disaster literature (see, for example, Burton et al., 1993; Blaikie et al., 1994; Kasperson and Kasperson, 2001), vulnerability is becoming an increasingly important concept in the fields of environmental and climate change (Cutter, 2006). Vulnerability is not static. The temporal context of vulnerability is of critical importance. Yet there have been relatively few historical treatments of vulnerability (Cutter, 1996: 533) and less still of how vulnerability to climate variability may have changed and may be changing over time (Parry, 2001: 258).

To some extent, this relative neglect is a function of three key problems: first, the multiplicity of definitions of and approaches to vulnerability and a general lack of consensus on the meaning of the term (Luers et al., 2003: 255); second, vulnerability is a concept, not an observable or tangible phenomenon per se, rendering it difficult to identify in the historical record; and third, we still possess only an imperfect knowledge of how the climate has changed over the historical period.

Adopting Cutter's terminology, there is certainly a 'confused lexicon' of meanings, interpretations and approaches to understanding vulnerability (Cutter, 1996: 530), reflecting a suite of epistemological orientations and contrasting frameworks. Various genres of literature, for example, have focused on vulnerability from the perspective of biophysical threats and hazards (Hewitt and Burton, 1971; Gabor and Griffith, 1980; Ambraseys and Jackson, 1981; Burton et al., 1993; Blaikie et al., 1994). Many 'unapologetically naturalist', physicalist explanations of disasters, for example, place total blame on 'the violent forces of nature' (Frazier, 1979; Foster, 1980; Blaikie et al., 1994: 11). These approaches position people as being implicitly vulnerable, owing to their presence in particular fragile or precarious environments. Adopting this perspective, those societies considered most vulnerable to drought, for example, would be those living in areas of low rainfall and sandy soils (Liverman, 1999).

Some more subtle biophysical based assessments have also incorporated demographic factors, such that concern focuses on the capacity of a particular environment to support a population. In recent years there has been a move away from attention on the stressors in vulnerability studies to the stressed system and its component parts and its ability to respond (Ribot, 1995; Clark et al., 2000). Social vulnerability, for instance, focuses on the 'susceptibility of social groups or society at large to potential losses' (Cutter, 2006: 72) from hazardous events and disasters. In these approaches, as Macnaghton and Urry (1998) suggest, 'cultural criteria are implicated in the definition and trajectories of even the most apparently physical environmental issues' (cited in Jones, 2002: 248). The nature of a hazardous events or condition is taken as a given or at the very minimum viewed as a social construct, not a biophysical condition (Cutter, 1996). This perspective thus highlights human coping strategies and responses, including societal resilience to environmental hazard, and positions biophysical threats as socially constructed phenomena. The most extreme of such approaches have been criticized for environmental denial (Burningham and Cooper, 1999: 306) and for fostering political quietism with respect to pressing environmental issues (Milton, 1996: 54; Demeritt, 2001).

Interdisciplinary research teams have now begun to explore vulnerability as a function of exposure, sensitivity and adaptive capacity, manifested within interactions of social and ecological systems (Turner et al., 2003). Vulnerability in this body of literature is conceived both as a biophysical risk as well as a social response (Cutter, 1996: 533). The impacts of an extreme climate event for a community, for example, would then be influenced 'as much by the level of technological, economic and political development as by the severity of the meteorological event itself' (Liverman, 1990: 49). The complex interaction between the environment and human society, however, represents a constraint that not only influences how livelihoods in a region may be vulnerable to disruption, and the way in which environmental change or an environmental or climate event is experienced, but also how different social systems and groups can respond or adapt to such events (Oliver-Smith and Hoffman, 1999: 73; Ohlsson, 2000).

Kasperson et al. (1988) and Kasperson and Kasperson (1996), for example, suggest that risks and hazards interact with cultural, social and institutional processes in such as way as to temper or aggravate public response (Cutter, 2006). Vulnerability, and hence adaptability, may thus change according to different scenarios and over time. Trajectory analysis can go some way to revealing these regional dynamics of change and, it follows, changing vulnerabilities (Kasperson et al., 1995). Messerli et al. (2000), for example, have suggested that the vulnerability of a particular society changes over time in conjunction with adaptive mechanisms and adjustments, some of which may in fact render society more vulnerable in the long run. They argue that there is a historical 'trajectory of vulnerability' through which all societies pass as they develop, economically, socially and technologically. The position of a society on this trajectory influences its relative vulnerability. 'Nature dominated' hunting and gathering societies, for example, are considered to be the most vulnerable to environmental and climatic changes. Societies who have modified their environments in order to buffer themselves from these changes, however, and who have developed productive agrarian-urban systems based on these adaptations are thought to be more resilient. With population expansion, however, and the overexploitation of and reliance upon these buffer systems, it is thought that the vulnerability of these societies once again increases. There has been considerable debate as to whether modern society is effectively becoming more or less vulnerable as a result of technological innovation and adaptation over time (see Meyer et al., 1998: 240–241; Messerli et al., 2003). Only through regionally focused, historical analysis of vulnerability, however, can such questions be adequately addressed.

## Climate Change and the 'Double-Sided' Structure of Vulnerability

There is now little doubt that the global climate is changing and human activities are exacerbating natural climatic variability. That the climate to which the world is currently accustomed will undergo further significant change is also indisputable. The details and implications of these changes, however, are less clearly understood. Such changes in climate are likely to pose new and significant challenges for society at large (Adger, 2003: 387) and for this reason climate change and its implications are increasingly being recognized as the most important influences on both biophysical and social vulnerability (O'Brien and Leichenko, 2000).

Unusually severe or prolonged drought, for example, ranks among the most devastating and calamitous of all extreme climate events, contributing to wildfires, crop failure, livestock death, food shortages and famine. Yet the vulnerability to extreme droughts is also thought to be increasing in many parts of the world (Baethgen, 1997), judging by escalating economic losses and a greater number of fatalities due to such events (Meyer et al., 1998; Kundzewicz and Kaczmarek, 2000; Easterling et al., 2001). Understanding why vulnerabilities are changing and how and why certain sectors of the population are disproportionately affected by drought, and investigating how people respond to its effects, are considered critical steps toward designing appropriate drought preparedness, mitigation and relief policies and programmes (ISDR, 2002).

Floods are also considered to be among the most common and yet most damaging of all extreme events. No other natural hazard occurs as frequently around the world or causes as much collateral damage (Kunkel et al., 1999; Kundzewicz and Kaczmarek, 2000; Changnon et al., 2000; Berz et al., 2001: 458; Kohle and Dandekar, 2004). The frequency and magnitude of floods from unexpected and unusual rainfall, but also associated with hurricanes and windstorms, is expected to increase in the next few decades in a context of predicted global warming and sea level rises (Kundzewicz and Kaczmarek, 2000; Changnon et al., 2000; Yin and Li, 2001; IPCC, 2007: 6). Yet vulnerability to floods and, it follows, flood losses, is also a product of anthropogenic change. Increasing deforestation, urbanization and river regulation and decisions to settle floodplains either through choice or due to land pressure, have rendered people in some locations effectively more vulnerable to flood risk. Moreover, although changes in technological development and agricultural practices can help to create a society that is effectively better able to survive the impacts of such events, they can also lead to over-dependence upon these systems. Indeed, it has been argued that a reliance on existing flood alleviation schemes has actually encouraged people to settle, build on or exploit lands in even higher risk zones (Kundzewicz and Kaczmarek, 2000). As suggested above, combined with population expansion, such developments can and will effectively increase the level of social vulnerability to the impacts of flooding over longer timescales (Messerli et al., 2000).

Climate change and weather events could also have important health implications. Climate can constrain the range of infectious diseases and can also influence pathogens, vectors, host defences and habitat, and many diseases are thought to be influenced by weather conditions or show strong seasonality (Patz et al., 2000, 2005). Global warming, however, is thought to be playing an increasingly important role in driving the global emergence and redistribution of infectious diseases, while extreme weather events may influence the timing and intensity of infectious disease outbreaks (Epstein, 1999, 2001, 2002; Patz et al., 2005). Variation in the incidence of vector borne diseases, for example, has been strongly associated with extreme weather events and annual changes in weather conditions (Zell, 2004). El Niño Southern Oscillation (ENSO) events in particular are often accompanied by weather anomalies that have been strongly associated with disease outbreaks over time (Epstein et al., 1997; Epstein, 1999; Pascual et al., 2000; Kovats et al., 2003). There is considerable debate about the precise nature of the health impacts of climatic changes, the nature and timing of the effects and their possible beneficial or adverse consequences (McMichael et al., 2006). Identifying the causal associations between climate, extreme events and disease outbreaks remains a major challenge (Kovats et al., 2003: 1482) and a better comprehension of the linkages between climate variability and disease should be seen as imperative if predictive models to guide public health responses are to be devised (Parmenter et al., 1999: 814).

Climatic changes will thus disrupt the way people live and interact with their environment and with each other (Chen and Kates, 1994: 3) and will pose challenges to future livelihood strategies for everyone (Bohle et al., 1994). Of course, unpredicted changes or extreme weather events, 'when climate surprises occur in unexpected places or with unexpected frequency' (Streets and Glantz, 2000: 99), have the potential to affect, and indeed disrupt, even the most robust of environmental, social and economic systems. It is anticipated, however, that the impacts of future climate changes are most likely to be felt more severely by natural resource dependent communities (Adger, 2003), and particularly by those societies in the developing world (Liverman, 1999). Agricultural economies are indeed thought to be more vulnerable to climatic hazards than industrialized ones, while conditions are most critical for environmentally, politically, socially or economically marginalized communities (Meyer et al., 1998; Cutter, 1996; Liverman, 1999), whose ability to adapt to and recover from environmental changes and biophysical events can be limited or constrained by limited access to natural resource or financial capital (Fraser et al., 2003; Mirza, 2003). People who live in arid or semi-arid lands, in low lying coastal zones, in water limited or flood prone areas, or on small islands are obviously especially vulnerable to climatic variability and any changes therein. The very young and very old are also often regarded as especially vulnerable, while differences in health, or access to health facilities, ethnicity, education, and learned experience with the hazard in question can all influence vulnerability (Meyer et al., 1998). Moreover, women in some parts of the world might also be differentially more vulnerable than men to environmental changes, particularly in developing countries where they are often responsible for agriculture, fuel wood and water management and hence are disproportionately affected by drought, deforestation and water pollution (Liverman, 1999).

Inasmuch as many climate change predictions have tended to be at best pessimistic and at worst apocalyptic (Liverman, 1999: 112), the predicted impacts for all these different sectors of society are similarly gloomy. Past climate impacts research, for example, and much of the continuing policy discussion has viewed climate change as something of a Malthusian threat to the world's overall ability to produce enough food and support a rapidly expanding population (Chen and Kates, 1994: 4). Vulnerability to climate change has been considered to be the very 'key to human security' (Bogardi, 2004: 362). Indeed, climate change, and an increasingly 'weaponized' world, have been identified as the two most important challenges facing the world in terms of international security (McBean, 2004: 183). Environmental security discourses, for instance, have drawn links between climate change, environmental degradation, economic decline and the debt crisis, and have positioned climate change as a high priority security concern, with the potential to stimulate or aggravate conflict and tension both within and between nations (Homer-Dixon, 1991, 1995). Moreover, by extension, the implications of climate change have also been highlighted as a potential cause of environmental migration, contributing to the movement of thousands of 'environmental refugees' across borders (Barnett, 2003).[2]

Although climate change undoubtedly poses risks to human welfare and as such represents a security concern, literature on such themes has been criticized for being more theoretically than empirically driven and for being motivated by predominantly northern geostrategic interests (Barnett, 2003: 8). Furthermore, the overemphasis on pessimistic prediction has tended to overshadow any net benefits that might be derived from climatic changes measurable through increased agricultural productivity, improved availability of key resources such as water, a reduction in some risks, such as those associated with flooding or decreased climate related expenditures. There has been a general reluctance among both scientists and policy makers to discuss the existence of any such positive outcomes lest they undermine efforts to secure global consensus on the implications of climate change (O'Brien and Leichenko, 2000: 223; 2003) and rightly so. This general pessimistic stance, however, has also, to some extent, obscured the fact that vulnerability to climate change does have an orienting function and that human societies are adaptable and have developed institutions and cultural coping strategies to deal with the impacts of environmental changes (Hassan, 2000; Fraser et al., 2003). This is particularly true of extreme or 'surprise' events which can, under certain circumstances, provide a 'window for positive change and impetus for remedial action' (Streets and Glantz, 2000: 100).

On this theme, Vogel (2001) has suggested that greater emphasis needs to be placed on the 'double sided structure' of vulnerability, that is to say, studies of vulnerability that also pay attention to adaptive capacity. Adaptation in this sense can be defined 'as an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects or impacts in order to alleviate adverse impacts of change or take advantage of new opportunities' (Adger et al., 2005). While most adaptation is reactive, in response to past or current events, it can also be anticipatory and planned (Smithers and Smit, 1997; Smit et al., 2000; Pelling and High, 2005: 1). Moreover, societies have an inherent capacity to adapt to climate change and these capacities are often bound up in an ability to act collectively (Adger, 2003: 388). Recent work focusing on 'social capital' responses has highlighted that environmental problems may be as likely to promote community co-operation as much as conflict between communities (Liverman, 1999: 112). Community engagement may thus offer a means of reducing vulnerability to natural hazards associated with climate change (Abramovitz et al., 2001). Although there has been an 'explosion of interest' in such studies of adaptation to climate change in recent years (Adger et al., 2005), there is still a need for a more comprehensive understanding of the pathways through which social resources are accumulated, on the influence of political structure on decision-making processes within communities and on the role of institutions and culture in shaping adaptive capacity and action (Pelling and High, 2005: 2).

Vulnerability is thus a composite and dynamic concept which means different things to different people (Cutter, 2006). It can be discussed in ecological terms, in relation to political economy or class structure and as a reflection of social relations and, in as much, represents a multi-layered and multidimensional social space defined by the determinate political, economic and institutional capabilities of particular groups of people in specific places at specific points in time. It follows that assessments of vulnerability need to be capable of mapping the historically, spatially and socially specific realms of choice and constraint that determine risk exposure, coping and adaptive capacity and recovery potential (Bohle et al., 1994). Such complex mosaics inevitably cast doubt on attempts to describe any general patterns and trends at global scales (Liverman, 1990) and justify the need for regionally or locally focused studies which are necessarily likely to be much more revealing. Yet, to date, relatively few studies have adopted such a multi-factor regionally based approach and fewer still compare the changing vulnerability of one place to another (Cutter, 2006: 116).

There are, therefore, still considerable gaps in our knowledge of climate changes themselves, but also exposure, sensitivity, adaptability and vulnerability of social and environmental systems to any possible changes in the future (Parry, 2001: 258). We have only an incomplete understanding of differential social vulnerability in different places through time and are only partially aware of the ways in which adaptations at different scales of human organization may interact and in some cases lead to differential or unexpected effects. Moreover, we do not know the extent to which adaptation might help overcome or exacerbate the diverse threats climate change poses in a more crowded and demanding world. Further work is needed to identify and integrate information about exposures, sensitivity and adaptability in the past in order to provide more detailed information about the potential impacts and responses associated with future climate changes (Parry, 2001: 258).

## Exploring Climate and Society in Mexico

Mexico represents one of the most climatically sensitive areas of the world (Wallen, 1955; Kutzbach and Street-Perrott, 1985; Liverman, 1993). The country lies in a latitudinal belt that is sensitive to fluctuations in atmospheric circulation and has, accordingly, experienced climatic change on the long (Heine, 1988; Bradbury, 1989; Metcalfe et al., 1991) and short timescales (García, 1974; Jáuregui and Kraus, 1976; Jáuregui, 1979; Metcalfe, 1987; O'Hara and Metcalfe, 1995). Such changes can be explained by present day climatic mechanisms.

The Mexican climate is influenced by two dominant atmospheric circulation systems. These are the trade winds, which deliver summer rainfall to the central and southern regions of the country when the Intertropical Convergence Zone (ITCZ) shifts northwards, and the subtropical high pressure belt, which brings stable dry conditions to the country during the northern hemisphere winter, when the ITCZ is displaced equator-wards. The northern part of the country is climatically distinct from the central and southern regions and tends to be marginal to the summer trade winds, though the northwest of the country is affected by the westerlies during the boreal winter, which can bring rainfall to this region.

The distribution and total annual rainfall across the country are determined by shifts in the strength and location of these dominant atmospheric circulation systems. Seasonality of precipitation, and variations therein, and the incidence of tropical storms also dictate changes in the temporal and spatial distribution of precipitation. Some drought events may relate to summer high pressure which can disrupt the flow of moist air, creating a mid wet season drought or canicula (Liverman, 1999).

A number of other climatic features play an influential role in the distribution of rainfall and annual precipitation totals. These include hurricanes and tropical cyclones, which typically affect both Caribbean and Pacific coasts between May and November, with September having the greatest frequency. Mid-latitude cyclones can bring rain, hail, sleet and snow. Severe thunderstorms, which form along or ahead of cold fronts, are also common during spring and summer months and are often accompanied by hailstorms (Mosiño Alemán and García, 1974). ENSO events are thought to represent the most significant cause of inter-annual climate variations across the country. Evidence of ENSO related rainfall anomalies for the instrumental period, for example, suggests that during warm ENSO (El Niño) events, an enhancement of the mid-latitude westerlies brings above normal rainfall to northern Mexico in the normally dry season between November and April, while a reduced flow of air across the country with the ITCZ well to the south results in drought and heavy frosts in central Mexico (Ropelewski and Halpert, 1987, 1989; Hastenrath, 1988; Cavasoz and Hastenrath, 1990; Magaña, 1999; Magaña et al., 2003). Cold (La Niña) events have been linked to lower than average winter rainfall in northern Mexico and higher than average summer rainfall in central Mexico. Climatic anomalies associated with recent ENSO years have thus resulted in widespread harvest failure and livestock losses, while there is also thought to be a link between hurricane frequencies and ENSO years.

Topographic features of course also exert an important influence on climatic characteristics and variation across the country. The Mexican plateau or high plain (Altiplano), which has an average elevation of 1,500 metres above sea level, is flanked on the western edge by the Sierra Madre Occidental and on the east by the Sierra Madre Oriental. These cordilleras can trap stable air masses, preventing them from entering the central Mexican plateau, and can also deflect winds. Trade winds from the northeast, over the Gulf of Mexico, for example, can be deflected southwards (through the Tehuantepec Pass), where they can become quite violent northerly blowing winds. Topography also plays a critical role in thermal variation and hence also rainfall distribution. Adiabatic cooling of air as it ascends over the cordilleras leads to the release of moisture in the form of heavy rains over the mountain slopes, this particularly being the case with the Sierra Madre Occidental, which is oriented at right angles to the surface trades that blow over the Gulf of Mexico. The extensive Altiplano also exerts an important thermal effect, heating air masses, leading to convective activity and thunderstorms during the summer rainy season (Mosiño Alemán and García, 1974). Frosts are also relatively common at high elevations, particularly between October and April. Dry atmospheric conditions in the Altiplano, however, can result in radiative cooling and frosts even during the summer months (Morales and Magaña, 1999). Indeed, frosts in June or July, such as those recently recorded in central Mexico (Eakin, 2005: 1926), can threaten rainfed crop yields.

## Climate History and Vulnerability in Mexico

Climate changes on a range of timescales have had implications for social and economic well-being throughout Mexican history and prehistory. Yet by the time Hernando Cortes and the first Spanish conquistadores arrived in Mexico in 1519, the region had been the site of some of the most advanced civilizations of the western hemisphere. A number of scholars have investigated the nature and diversity of landscape changes associated with the climate risk avoidance strategies of such 'traditional' and pre-Hispanic agrarian societies (Wilken, 1987; Whitmore, 1992). The most significant agricultural adaptations to climate variability, periodic drought and the constant threat of water scarcity for agrarian communities, however, involved the storage of water and the use of irrigation. Permanent and ephemeral watercourses, rivers and arroyos had long been exploited by pre-Hispanic populations for irrigating *milpas* (maize plots), garlic and beans.

Though for the most part successful, such adaptations may have failed to buffer societies against the most extreme weather. Prolonged drought coupled with 'killing' frosts in central Mexico between 1452 and 1455, for example, is thought to have contributed to widespread harvest loss, culminating with the famine of '1 Rabbit'. This stimulated out-migration, disease and death (Hassig, 1981; Therrell et al., 2004). Though undoubtedly one of the most widely reported social calamities in Mespamerican history, this event was not unique (Therrell et al., 2004) and similarly dramatic episodes have been documented both before and after this time.

Following the conquest of the Aztec capital at Tenochtitlán in 1521, Spain was to rule Mexico as part of the viceroyalty of New Spain for the next 300 years until 16 September 1810, when the battle for independence (finally gained in 1821) began. Although many of the strategies developed to cope with the threats posed by the Mexican climate were maintained in the colonial period, and other adaptations and coping strategies would be developed, the features of the colonial political economy are thought to have created a society and an economy that was differentially more vulnerable to the impacts of climate change and weather events (Liverman, 1999).

The timing, impacts and responses engendered by historical climate variations and weather related events in Mexico have only recently begun to be investigated. A key obstacle has been the lack of adequate, long-term data with sufficient resolution to investigate changes in local weather conditions and also the social and economic implications of these changes (Ingram et al., 1981; Easterling et al., 2001; Houghton et al., 2001). Short-term extreme events in particular require high temporal resolution observations, but widespread instrumental weather data rarely cover periods before the middle of the nineteenth century (Metcalfe, 1987).

Investigations of lake basins in the north of Mexico and in the neovolcanic highlands of west central Mexico, however, have revealed significant spatial variability in climatic signals across Mexico over the late Pleistocene and Holocene, resulting from the influence of different moisture sources in response to external forcings. Northern and western Mexico came under the influence of Pacific mid-latitude frontal systems during the last glacial. The Holocene also shows high variability, with changes (especially drought periods) that may have contributed to shifts in population distribution (Metcalfe et al., 1994).

Palaeolimnological analysis of sediment cores taken from lakes elsewhere in Mexico has been similarly revealing. Analysis of lake sediments from

Punta Laguna in the Yucatan Peninsula, for example (and also from Lake Peten Itza in the lowlands of Guatemala), has indicated climatic changes on multi-decadal and millennial scales (Curtis et al., 1996, 1998; Hodell et al., 2005a). The period between 1785 and 930 years BP was thought to be particularly dry (with exceptionally arid events centred around 862, 986 and 1051 AD) and is recorded at several other sites in Mexico and Central America more generally. This period coincides with, and indeed has been linked by some authors to, the collapse of the Classic Maya Civilization, when urban centres faced depopulation and trading decreased across a broad region (Curtis et al., 1996).

Other, more recent periods of climatic change have also been recognized from similar sources. Analysis of sediments drawn from Lake Aguada X'caamal in the northwest Yucatan Peninsula has revealed that the climate became drier in the region in the fifteenth century AD, round about the time of the onset of the Little Ice Age. Comparison of the results from the Yucatan Peninsula with other circum-Caribbean palaeoclimate records indicates a coherent climate response for this region at this time (Hodell et al., 2005b).

The expanding network of tree ring studies is also playing a pivotal role in the reconstruction of Mexico's climate history. Tree ring investigations by Cleaveland, Stahle, Therrell and Villanueva Diaz have provided superb records of historical precipitation variations in various regions across the country. Dendroclimatological evidence supports lake sediment evidence of prolonged periods of drought, or megadrought in the eighth and ninth centuries (Acuña-Soto et al., 2005), while Cleaveland et al. (2003), Dias et al. (2002) and Therrell et al. (2006) have highlighted other periods of sustained, extreme drought across northern Mexico which are thought to have affected agrarian livelihoods and may have also contributed to social and political instability. Identification of megadrought in the 1550s, for example, which is thought to be one of the most severe droughts in North American history, has been forwarded as an underlying cause of indigenous revolt at this time (Cleaveland et al., 2003: 370). This megadrought may have also interacted with prevalent ecological and sociological conditions, magnifying the human impact of infectious disease in central Mexico (Acuña-Soto et al., 2002). Interestingly, the occurrence and impacts of such extreme droughts in central Mexico has been found to corroborate Aztec climate folklore (Therrell et al., 2004).

Historical documents represent another source of high quality climate information at the fine temporal resolution needed to identify past climate fluctuations (Brown and Isaar, 1999; Bradley, 1999). Historical records charting the impacts of extreme events, coping strategies, technological adaptation, narrative, ideology, regulation and recovery have long been recognized as valuable sources for reconstructing climate during the last few centuries when no instrumental or similar sources are available (Garcia-

Herrera et al., 2005). Indeed, over the past two decades, climate historians working in various regions of the world have refined and improved methodological approaches and have identified new documentary and proxy sources of climate information. Such sources have been used extensively to reconstruct historical ENSO events (Quinn and Neal, 1992; Ortlieb, 1999), as well as changes in the North Atlantic Oscillation (Jones et al., 1997; Luterbacher et al., 1999) and there have been a number of documentary based studies of regional climate variability across Europe,[3] the Americas,[4] Africa,[5] and Asia[6] and also over the Pacific and Atlantic Oceans.[7]

Inasmuch as historical documents can be used for the reconstruction of climate variability, however, they can also offer invaluable and, to some extent, unique insight into how people perceived, were affected by and reacted to a variety of climate changes and associated impacts. Travel accounts and descriptions, legal documents, crop and tax records, as well as maps, paintings and images have all been used to identify the timing and chart the impacts of and societal responses to anomalous weather and extreme events over the historical period in various parts of the world. The very rich colonial archives of Mexico present similar opportunities. The Spanish colonial administration, both in Spain and in Mexico, began compiling a series of document collections on population, settlements, landscapes and economic resources for the different regions of Mexico immediately after contact (Butzer, 1990). This has resulted in a legacy of archival data in the form of national and regional level fiscal and judicial documents now housed in the various national, state level and local archives and libraries of the country.[8]

A number of regional archival investigations have highlighted the different document groups (ramos) and historical sources that can be employed to reconstruct microscale environmental characteristics and to identify the environmental impacts of post-Conquest changes in land use and tenure (Melville, 1990, 1994; Butzer and Butzer, 1993, 1995, 1997; Endfield and O'Hara, 1999; Sluyter, 2001, 2002). Investigations have also used these sources to explore the relationship between agricultural and economic crises and periods of drought (Swan, 1981; Florescano et al., 1995), and to investigate the connection between water shortage and conflict over water access and water rights (Lipsett Rivera, 1990, 1992, 1999a, 1999b; Meyer, 1997; Endfield and O'Hara, 1997). Recent research has also demonstrated the potential of these colonial documents for reconstructing climatic chronologies and for investigating the impacts and responses engendered by extreme weather events in different regions of the country over the last six centuries (Metcalfe, 1987; O'Hara, 1993; García-Acosta, 1993; O'Hara and Metcalfe, 1995; Endfield et al., 2004a, 2004b; Endfield and Fernández-Tejedo, 2006). The present study makes use of a variety of colonial archival sources, housed in national and regional, public and private archives of Mexico, to further explore the complexities of the relationship between climate and society in colonial Mexico.

## Case Studies and Approach

This study focuses on three regions covering a range of environmental, social, economic and political contexts and histories and located at key points along a north-south rainfall gradient: the Conchos basin of Chihuahua in the arid north, the central Valleys of Oaxaca in the wetter south and Guanajuato located in the central highlands, a region of climatic transition. As shall be illustrated in the following chapters, each region had very different environmental and climatic contexts and pre-Hispanic histories and developed very different settlement and land use characteristics during the colonial period. Guanajuato had a long history of pre-Hispanic settlement, but by the time Spanish arrived, the area represented something of a frontier zone. Nonetheless, the combination of fertile soils and mineral wealth meant that by the second half of the sixteenth century, the area had developed into the country's main agricultural centre, specializing in the production of wheat, fruits and vegetables. In contrast, the central valleys of Oaxaca retained much of their pre-Hispanic indigenous character throughout the colonial period and, although livestock and Mediterranean cultivars were introduced into both areas, people there continued to focus on the production of maize, beans and chile, employing traditional cultivation methods. Significantly, there was a good deal of land retention by indigenous populations in this region. In Chihuahua, the threat of violent attacks by the hostile nomadic indigenous groups who occupied the northern part of Mexico delayed European colonization of the region. By the start of the seventeenth century, however, a lucrative mining and livestock economy had begun to develop. Investigating the relationship of climate and society through these case studies might shed light on the complex climatic relationship between northern, central and southern regions of the country, but also provides a unique insight into the way in which vulnerabilities and adaptations to disaster changed through time and across different contextual spaces. The case studies selected also provide an opportunity to explore how predominantly indigenous societies, as well as those with a more European structure, understood, coped with and articulated knowledge about climate change.

The nature and origin of the documents that can be used to investigate climate variability, impacts and implications for society in these regions are extremely diverse and require some consideration. The Archivo General de la Nación (AGN) is home to one of the richest manuscript collections on the history of the Americas. There are in total 115 ramos (consisting of over 300,000 individual documents) dealing with colonial New Spain alone now comprehensively indexed on a CD-ROM index. A variety of ramos held in the AGN and noted in table 1.1 were consulted for this study. As well as the manuscript collections held in the national capital, there is also a rich store of state level and local archives, both civil and ecclesiastical. The present study made use of unpublished, handwritten documents held in several private and public archives in the case study regions, including the Archivo General del Estado de Oaxaca (AGEO), Archivo Historico Municipal de Oaxaca (AHMCO) and the Archivo Privado de Don Luis de Castañeda, all in Oaxaca City; the Archivo Historico Municipal de Leon (AHML) and the Archivo Historico del Estado de Guanajuato (AHEG) in Guanajuato; and the Archivo Historico Municipal de Fondo Colonial, Chihuahua (AHMCH) and Archivo Hidalgo de Parral, Chihuahua (AHP). A number of the many libraries and museums in Mexico City also have archival repositories open to public consultation. A variety of published texts and unpublished documents now filed on microfilm were consulted in the library of the Museo Nacional de Antropología, including original documents, and photocopies of documents, dealing with all three case studies, that are now housed in libraries in Paris (Bibliothèque Nationale de Paris) and Spain (Archivo General de Indias). Tables 1.1 and 1.2 demonstrate the range of ramos (document groups) that were employed in this investigation and the nature of the typical content.[9]

Manuscripts in each ramo were read in chronological order. Documents were scrutinized for references to weather or weather related information, falling into three approximate classifications: first, direct descriptions of extreme or damaging weather events such as drought, floods, storms, 'killing' frosts, hail storms; second, general observations of contemporary climatic conditions, such as the early, late or non-arrival of the summer rain season, seasonal frosts, changes in the characteristics of perceived 'normal' weather conditions and the implications of this, particularly for agricultural communities, but also for health and social well-being more generally; and third, indirect evidence of climate variability, such as that derived from information on harvest gains or losses, problems of food or water scarcity, disputes and legal proceedings over natural resources (including water), instances of crop blight, marked variations in grain prices, migration, land or property abandonment, pestilence and epidemics (human and livestock). Relevant passages were all excerpted and transcribed. A wide variety of published chronicles, diaries, journals and travelogues were also consulted for references and observations on weather and its implications.[10] Wherever possible, every effort was made to corroborate evidence with multiple references, and to compare archival with other lines of climate change evidence derived from other written sources or, where available, independent dendrochronological and archaeological evidence of climate variability and change.[11]

**Table 1.1** Document groups (ramos) consulted in the Archivo General de la Nación (AGN), Mexico City

| *Ramo* | *Content* |
|---|---|
| Tierras | Disputes over land and water/natural resources |
| Mercedes | Land grants |
| Indios | Indigenous affairs |
| Ayuntamientos | Local authority records |
| Rios y Acequias | Information on rivers and water works |
| Caminos y Calzadas | Information on roads and routeways |
| Historia | Historical information for various regions, compiled at close of eighteenth century |
| Obras Publicas | Documents pertaining to public works projects |
| Industria y Comercio | Materials pertaining to trade and commerce of various goods/trading infrastructures and networks |
| Tributos | Indigenous tax records |
| Alhóndígas | Crop records/information on goods held in public food store |
| Audiencia de Mexico | Documentations relating to the administration of New Spain |
| Archivo Historico de Hacienda | Affairs of haciendas and landholdings/ includes correspondence |
| Hospital de Jesus | Documents pertaining to the administration of the Marquesado del Valle, Oaxaca (see chapter 3) |
| Jesuitas | Information on Jesuit property |
| Temporalidades | Information on Jesuit property subject to redistribution after their expulsion in 1767 |
| Carceles y Presidios | Prison and garrison records |
| Provincias Internas | Documents pertaining to military command of northern frontier |
| Misiones | Mission records |
| Alcades Mayores | Provincial level administrative records |
| Media Anata | Tax paid tied to incomes derived from any ecclesiastical benefit, pensions or use |
| General de Parte | Requests, complaints and demands forwarded to Viceroy and/or local council |

There are of course a number of problems with using archival sources for investigating the impacts and perceptions of and vulnerability and response to extreme events. In the absence of independent climatic evidence, recorded information of climate variability and weather events cannot at once serve

**Table 1.2** Document groups consulted in the regional archives in Oaxaca, Guanajuato and Chihuahua

| *Regional archive* | *Ramo* | *Content* |
|---|---|---|
| Archivo General del Estado de Oaxaca (AGEO) | Alcadías Mayores and Real Intendencias | Local, political and economic issues, litigation over resources and land, correspondence between hacienda owners, property inventories, details of harvest problems |
| Archivo Historico Municipal de Oaxaca (AHMCO) | Actas de Sessiones de Cabildo | Municipal council minutes |
| Archivo Privado de Don Luis de Castañeda | Not named | Various. Focused on hacienda documents, deeds, transactions, maps and legal disputes over land |
| Archivo de las Notarias, Morelia, Michoacan (ANM) | Tierras y Aguas | Disputes over land and water |
| Archivo de la Ciudad de Patzcuaro (P) | Not named | Various documents pertaining to barrios and pueblos in the region |
| Archivo Historico Municipal de Léon, Guanajuato (AHML) | Notarias | Various documents pertaining to periods of agrarian crisis and impacts |
| Archivo Historico del Estado de Guanajuato (AHEG) | Actas de Cabildo | Municipal council minutes |
| | Ayuntamiento | Local authority record |
| | Actas de Cabildo | Municipal council records |
| | Guerra | Details of defence needs and indigenous attacks on northern frontier of Mexico |
| | Provincias Internas | Information on unrest on the northern frontier of Mexico |
| | Haciendas | Information on properties and landholdings in Chihuahua, plus information on epidemic and agrarian crisis |

as both meteorological evidence and evidence of the human impacts of climate (De Vries, 1980). The purpose in this study is not to produce a chronology of climate changes or events per se, but there are other problems associated with subjectivity, bias, discontinuity in the historical record and inconsistency that need to be considered. As primary sources written by individuals from particular perspectives and for a specific intended audience, the colonial records used in this investigation, for example, were produced within a certain context and contain both intentional and unintentional biases. There may well have been instances where there was deliberate sensationalism of the impacts of particular flood or drought events in order to secure financial aid, tax relief or to challenge existing rights of access to water. There is also no uniform and agreed definition of what constituted a weather or weather-related event such as a flood, storm, hurricane or drought. Unusual, anomalous or extreme events were judged against what was perceived to be a normal range of variations, which itself was a function of the nature and span of an individual's experience and the average range of variation communicated through oral histories or historical knowledge (Hassan, 2000).

Risks interact with social, cultural, economic, psychological and institutional processes in ways that either amplify or dampen public responses (Kasperson et al., 1988). Society selects which risks or hazards to emphasize and which ones to ignore, often reflecting moral, political and economic choices that are in themselves socially constructed and value laden. Thus, if the climate variability or an unexpected weather event resulted in only limited human impact and economic loss, then there may well be no record of it having taken place (Douglas and Wildavsky, 1982). There may, in addition, have been periods when events themselves caused sufficient disruption in the administrative systems responsible for record keeping to lead to a gap in the record for a period when data is most needed (Landsberg, 1980). For all these reasons, archival investigations of the implications of climatic variability and extreme weather events will inevitably be subject to error.

The colonial archives thus provide at best only a partial record of past events. Furthermore, deriving insights about the contemporary and future vulnerability of Mexican society from such dramatic examples is, of course, problematic. Problems of chronological resolution, insufficient data and oversimplification can hamper the value of using such historical examples as analogues to glean insights about the potential implications of contemporary or predicted climate change scenarios (Meyer et al., 1998; McNeill, 2005: 178). The fact that past societies differ markedly from those in the modern world makes simple analogies or parallels unrealistic (Ingram et al., 1981: 5; Meyer et al., 1998). It should also be remembered that major events, particularly those which leave discontinuities in the historical record, do not always require major causes (Coombes and Barber, 2005: 303) so much as a suite of social, economic, political, demographic and environmental factors that have the potential to coalesce at a particular point in time to cause dislocation, and invariably only then for a particular culture group or sector of society.

Yet equally, while there is a good deal of uncertainty with respect to climatic futures, the value of looking to the historical record to learn about societal vulnerability to climate events should not be underestimated (Bradley, 1999), especially in climatically sensitive regions of the world such as Mexico. Exploring the experiences of individuals, groups and places in the past could help us understand how flexible (or rigid) societies are, or have been, in dealing with climate related environmental changes and might also help us to identify the most vulnerable societies and places (Meyer et al., 1998: 218; Swetnam et al., 1999). Indeed, knowledge of successes and failures in adaptation to past climatic variability might possibly increase the ability to respond to the threats of long-term climate changes (Tompkins and Adger, 2004). Thus, inasmuch as there is a need to develop more comprehensive assessments of changes in weather and extreme climate events over longer timescales (Jones, 1988: 544; Vogel, 2001), it is also vitally important that the impacts of and social response to these changes are explored. It is hoped that the following chapters reveal that, as expressions of contemporary environmental awareness and perception at least, such documentary sources can offer some insight into how different sectors of colonial Mexican society conceptualized, understood, adapted and responded to climate change and its implications.