PARTING THE WATERSHED: THE POLITICAL ECOLOGY OF A CORPORATE COMMUNITY IN THE SANTA CRUZ RIVER WATERSHED, SONORA, MEXICO.

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ABSTRACT

Ecological change very often parallels social change. The concept of the social-ecological system (SES) provides a holistic means of accounting for the dualistic nature of human-environmental interactions by acknowledging that social, political and economic factors influence and are in turn influenced by the processes of ecological change. These transformations can be contextualized within nested adaptive cycles of change that respond to pre-existing conditions and which provide new opportunities for system actors. The adaptive cycle also grants that processes of social and ecological change may be permanent, irreversible and result in new configurations not previously imaginable. The ability for an SES to respond to these processes of change depends upon its *resilience* which defines the range of reversible change within a stable state. Resilience is determined by a system's vulnerability, by the pre-existing or available capital.

Within this dissertation, I assert that resilience is an important factor to consider in studying arid land political ecology. Resilience can be influenced by both institutional and environmental factors. I assert here that institutional factors alone cannot explain the pace of change in a particular political ecology. While institutions constitute the dominant signals with regards to economic decision making, environmental signals may be ultimately more significant. I utilize a detailed case study focused upon a watershed and ejido in northwestern Mexico. This case study demonstrates the influence of strong political and economic signals that influence local economics. Nature bats last and can exert powerful forces over institutional choices. Using this case study, I demonstrate how a dramatic shift

in climatic as well as hydrologic regimes leads ultimately to a general degradation of agropastoral ecological resources and their replacement with new, stable but less desirable states. Land-use has subsequently changed. The latter set of ecological changes has become a sort of death of a thousand cuts that has reduced the community's ability to tap local natural capital and thereby generate economic capital. This study is intends to contribute to our knowledge of political ecology by evaluating the concepts of ecological resilience, multiple stable states, and adaptive cycles to the study of these social-ecological systems.

CHAPTER ONE: INTRODUCTION AND NATURE OF THE PROBLEM

A Cautionary Tale: "*¡Aguas!*"

During the mid-17th century, colonial Mexico City grew at a phenomenal rate. As the capital of New Spain, it was rapidly transformed from recently conquered town largely dominated single-story architecture to a burgeoning community where multi-story buildings sprouted across the busy landscape and where the basic core of the modern city took shape. Not unlike the 21st century incarnation, the capital's busy roadways between city blocks were filled with an intense mixture of pedestrians, vehicles and merchants. Beneath those busy streets, however, was only earth--Mexico City lacked underground sewage transport, disposal, much less such a modern luxury like wastewater treatment. In fact, most buildings lacked any kind of indoor plumbing whatsoever that might have served to get the waste to the then non-existent sewage system.

Instead of sewage disposal and treatment, as in much of Europe, people living in the densely packed quarters of the multi-story buildings were forced to utilize bedpans and "night pots" for the storage of human waste. Disposing of these wastes was simply a matter of going to the nearest window and hurling the contents into the street below, hopefully not hitting the many passersby below. The method for warning them was to shout "*¡Aguas! ¡Aguas!*" into the busy street below. Duly warned, pedestrians in the street would move quickly out of the way--or so it was hoped. (Etiquette in the Colonial-era city also demanded that women be escorted on the street-side of a side walk, ostensibly to prevent any waste from hitting them, and at the same time wide-brimmed hats were theorized to be keep more than just the sun or rain off of people's heads. If either of these two historical hypotheses is correct, then the actual efficacy of the warning might indeed be questionable.)

Given time, the phrase "*¡Aguas!*" became a common part of Mexican colloquial Spanish. But it has become much more than just shorthand for "watch out as I'm hurling human excrement out of my window and into the street below!" In fact, "*¡Aguas!*" can also be used in other contexts such as "*Viene tu papá y esta enojado. ¡Aguas!*" (Here comes your father and he's mad. Watch out!). Or it might be used to caution someone walking the cattle ranges of northern Mexico that they are about to inadvertently step into cow dung. The phrase *¡Aguas!* has essentially evolved to become an instantly recognizable call for caution in Mexico.

The dual meaning inherent in the phrase *¡Aguas!* (caution/water) is an appropriate metaphor for the case study detailed in this dissertation because the story I will tell as a result of that study is also a cautionary tale. It is also one involving and, in fact, revolving around water and the landscape responsible for its production and quality-the watershed. The tale I will unfold here is one that cautions against the abuse of water and the watersheds that generate increasingly scarce waters of northern Mexico, where it is, in fact, the limiting factor for all ecosystems, including human ones. Water, however is not the only focus of this research--because it is the state of vegetation, soils, and landscapes that determines the quality and quantity of water available to inhabitants of a watershed. Therefore, this cautionary tale of *aguas* includes also a significant if not dominant discussion of *tierras* (or lands) too. In this dissertation, I will discuss how national-level changes in Mexican tenure have changed irrigation water and rangeland management in an arid land ejido (San Lázaro, Sonora), and what are the consequences of these changes for the portion of the Santa Cruz watershed controlled by the community.

And like any limiting factor, water is a good place to begin. In the Sonoran Desert, during the long hot days of June, before the North American Monsoon brings a wet wave of tropical rains, it is nearly impossible to avoid thinking about water. This time of year, there is, in fact, nowhere in the desert where you cannot feel the pull of water. If you happen to be out walking in the heat, water oozes out of your pores, and evaporates rapidly into the air around you like an invisible haze. In the soil, it retreats from the sun, deep into the ground to where only the burrowing roots of mesquite or palo verde trees can reach it. Only dust and sun are left behind. For all living things in the desert this time of year, the quest for water becomes an obsession to occlude all others. For most of them, there are but three choices: find water, sit tight until you get some, or die.

For those that can move quickly, the rare streams in the desert become life giving. For those that move slowly (like plants), they lie in wait, or point their roots towards the darkest, moistest reaches of the soil. Many of these plants depend on the rare ephemeral stream or arroyo to provide this subsoil moisture. Hence, the rare free-flowing streams of the Sonoran Desert provide something that is absolutely irreplaceable for the vast majority of desert dwellers-ready water (Hendrickson 1985). This dry fact of life for desert living is completely compelling when it comes to human desert dwellers too.

For that reason, water has been and continues to be the singular obsession of nearly every culture and society in the deserts of the Greater Southwest. And our search for ways to get it, harness it, own it, mine it, transport it, and keep it clean enough to use will plague us forevermore. This study deals with one small case of how people in the desert have and continue to seek out water, as well as to fight or cooperate over its use. It also focuses on the ways that one such group is struggling to build an ethic of respect for water and watershed resources in the face of precipitous drops in quality and quantity after decades of landscape and climate change. The results of that struggle have had both positive and negative consequences for the desert ecosystems dependent upon these same waters. In the long run, it is possible to demonstrate how human activities in the desert, transformed by a progression of different cultures, institutions, and economic systems, have undermined their life-giving desert water sources and riparian ecosystems.

Along with livelihood, health, and prosperity, water is a singular focus for the people of San Lázaro, Sonora, where the research for this study was gathered during a twelve-month period in 2002 and 2003. When San Juan's Day passes every June 25th, San Lazareño rancher-farmers look heavenward and pray for rain to re-green the parched grasslands of their home. When the rains do not come, ranchers complain bitterly-it is a matter of life and death for their cattle, and hence, hunger or surplus for their families. One particularly dry spring day, still nearly a month before the advent of the day that San Juan purportedly miraculously brought the rains to a dry Middle Eastern land over 3,000 miles away, a group of cattle wander the town plaza. I commented on this and a community member informs me that: "*es un señal muy mal-indica que no hay pasto en los potreros cercanos,*" that's a very bad sign-this means that there is no grass in the nearest pastures. The heavily grazed rangeland had not recovered, nor had the riparian forest where cattle often congregated after the grasses disappeared. The rains were scarce thus far this winter and spring. The Pacific frontal storms that water the desert in the cool season had failed for a fourth year. So, unless the rains fell consistently and heavily during the remaining spring months, this looked to be a year of certain privation and desperation. If rains did not come in time to water the pastures, ranchers would be forced to sell underweight cattle to cattle buyers at cut-rate prices, or purchase expensive forage to feed them through the driest period. Either way, they would lose money.

What is so miraculous about this picture of desperation and impending hunger is that the community of San Lázaro and its contiguous ejido, Miguel Hidalgo, was once home to one of the richest rangelands in Northwestern Mexico and supported a prosperous farm along the banks of a deep and perennial reach of the Santa Cruz River. At its height, the ranch boasted year-round livestock numbering in the thousands (Sonnichsen 1974). Prior to the 1960s, as the westernmost division of the Cananea Cattle Company under capitalist Colonel William Greene, lands now occupied by the ejido supported vast cattle herds, abundant wildlife and championship thoroughbred horses pastured along the river. What happened in the ensuing years that have lead to these difficult circumstances? Why were rancher-farmers there struggling against such insurmountable environmental conditions in 2003?

The answers to these questions come from the confluence of many different threads.

A major portion of the answers can be found in the history of San Lázaro as well as its watershed, the development of its water and land use practices and tenure regimes. Governance plays an important role too in this in that inconsistent, oftentimes corrupt federal government mismanagement of ejido land and water resources as well as shifting economic development priorities. In the latter case, priorities shifted dramatically when neoliberal economic policies were implemented nationally and internationally. At the end of this roller coaster of external administration, the *ejidatarios* have been left with difficult, private management decisions, converting a communal economic logic into an individual one. A major portion of this dissertation will be devoted to describing the history of land use, governance, and tenure in San Lázaro.

Another significant contributor is the environment itself—changes that began with or at times preceded shifts in anthropogenic land use, climate and hydrologic processes. This history, like that of the ejido and its uneven development, is multifaceted. The most important factors and their outcomes are not always clear, nor do they lend themselves to a logical, cause-and-effect description. Yet, even if we cannot disentangle the relationships between the hydrologic, climatic and biophysical processes involved, land and water resources upon which this community depends are heavily degraded and are therefore less sustainably managed using the individualistic philosophy of modern neoliberalism in Mexico. Environmental change undermined livelihoods prior to the implementation to new economic policies that left local land users ill-equipped to deal with the ramifications of the changes themselves. This is not a "chicken-and-egg" paradox but rather an example of how non-linear environmental and economic processes interact to increase livelihood instability, risk and further degradation. The century-long process of watershed degradation and the consequences of modern-day privatization reveal the delicate ecological services upon which arid-land ejidos such as this one survive. I will attempt to trace those historical and ecological processes while demonstrating how their confluence makes the current neoliberal vision for the ejido inappropriate for adapting to current circumstances.

Recent Political Economy of Mexico

These processes must also be placed into a larger context, within the Santa Cruz River watershed, as well as the U.S.-Mexican borderlands. This dissertation will describe the shifting political economic terrain upon which San Lázaro sits. The fault lines of that terrain are as important to the political ecological processes outlined here as the ecology of the community itself. These new trends lie within the areas of governance and economics, and are distributed along continuum that range from formal, centralized governance to informal decentralized bodies, while economic strategies range from engagement in the overt economy to the covert (illegal) economy of the border region.

Beneath these problematic trends, however, lies a more important set of questions revolving around the advent of neoliberalism in agricultural development in Mexico. On the surface, Mexico's decade-old, neoliberal efforts to privatize its communally managed ejidos have serious implications for the environmental sustainability of these agrarian communities, particularly in arid regions. While the privatization of water and land tenure arrangements in

Ejido Miguel Hidalgo illustrates this trend, it also reveals some critical questions around the distribution of environmental and economic risk in rural societies when tenure is re-engineered by neoliberal policies. If common-pool resources are communally managed in order to minimize both the environmental and economic risks inherent in their extraction (McCay and Jentoft 1998; Park 1992, 1993), what happens when those resources are privatized? How are those risks (and benefits) redistributed across households, groups, and whole strata within rural society? By focusing on the case of privatizing land and water-the latter being the most important limiting resource in an arid environment—I will explore the ways that economic and environmental risks are spread within both communal and private tenure regimes. As Hornborg (2001: 1) defined it, power is the "social relation built on an asymmetrical distribution of resources and risks."

Exploring these processes allows us to delve deep into the political ecological transformation of the Mexican countryside, one that is resulting in the dislocation of traditional rural economies, the production or exacerbation of environmental degradation, and the replacement of post-Revolutionary systems of production with covert, often illegal economies based in part, on the proximity of the region to the U.S.-Mexican border. Because the community of San Lázaro sits just a stone throw from that border, and along a critical environmental corridor constituted of the bi-national Santa Cruz River, the political ecological transformation is all the more important to understand (Marshall, 2003: 7).

Ultimately, however, this case study traces how changes in tenure relate to land and water management. Those changes influenced and were in turn heavily influenced by the environmental realities of the watersheds in which San Lázaro is situated. By looking to these kinds of landscape-level changes, along with climate variability that has exerted a strong influence on the entire region, we can piece together the cautionary tale that constitutes the political ecology of smallholder ranching in northwestern Mexico as it evolved over the last century, only to be transformed by the 21st into an endangered, extremely risky livelihood. As will also be illustrated by this study, the endangerment of that livelihood also hurts our chances of conserving the working landscapes that shape it or that have been shaped by it.

Theoretical Context & Contribution

Theoretically, the case of San Lázaro, Sonora has some distinct scholarly underpinnings that should be explained before moving on. These include political ecology, cultural ecology, land tenure studies, and environmental studies. The first two are intertwined in their pedigree, while the third reflects broader concerns with peasants, economics, and householding. The last area encompasses a wide swath of current thinking on environmental change in the desert southwest, including arroyo formation, hydrology, vegetation change, range management, and climatic change. Current debate and contributions from studies of ecological resiliency in socio-ecological systems (SESs) constitute an important part of this literature and will be treated in greater detail later.

I will use Chapter Three to discuss the theoretical contributions this case study lends to political ecology, and how the subfield can be advanced by applying new ecological theory from non-equilibrium systems as well as insights from recent watershed management discourses. In order to do so I deconstruct some political ecology's approaches to arid systems, critique aspects of them, and look for patterns relating particularly to ecological theory within the burgeoning literature. I will make the argument that political ecologists on the whole have been sensitive to the issue of ecological balance or equilibrium but also have often clung to a thread of ecosystem theory that relies heavily on *prima facie* assumptions about the overall environmental context of a particular society or case study in question. In the case of arid lands, reliance by some authors on outdated ecological assumptions has led to gaps in our understanding of the dynamics of environmentally chaotic biophysical regimes. The lack of fit has important political ramifications that have very often been built into economic development models. Where the fit is particularly poor, both local resource users and the ecosystems they depend upon suffer as they move into new, less useful ecological states.

Proponents of political ecology often struggle to relate variables through multiple levels of analysis (cf. Vayda and Andrews 1999: *passim*; Pelto 1992: 259). I argue that a watershed-scaled approach helps the researcher to nest and integrate the plethora of variables involved a political ecology case study. Through upstream and downstream relationships, as well as upland and bottomland influences, watershed approach allows the author to build a case for how local-level phenomena are impacted by higher-level processes as well as relating those phenomena with environmental consequences. Furthermore, scale adds an important hydrologic component to the case study of arid land political ecology.

This component has been much-studied by the likes of political ecologists (cf. Donahue and Johnston 1998; 1992, 1993; Sheridan 2001; Walsh 2004), but often as a separate focus from land management concerns that ultimately influence watershed-scale hydrologic processes. Lastly, analysis at different scales (regional, watershed, and community) allows us to discern the linkages between ecological and political economic processes that lie at the heart of political ecology.

New, non-equilibrium-dependent theories may contribute to the utility of the political ecology approach in arid settings and they will guide the discussion of rangeland ecology in this case study. Work by the Resiliency Alliance (e.g. Gunderson and Holling 2002; Walker et al. 2006) is particularly important to this study and because of its sensitivity to highly variable environments and cyclical changes. The patterns implied by these models of socio-ecological systems (SESs) suggest some understanding of abrupt change in managed resource systems, particularly as managers are influenced by extra-local processes in ecology and policy. Resiliency theory also builds a conceptual framework—called the "panarchy cycle"—for placing local patterns of resource utilization within cycles of innovation, exploitation, conservation and revolution. This pattern is predicated upon an understanding of natural (or ecological) capital that is transformed throughout the cycle, largely by the interaction of social and ecological variables (the SES). Chapter Two will describe that capital and lay out a major portion of the case for how its transformation fits within the panarchy cycle.

As I will describe in Chapter Two, highly variable, non-linear arid systems such as the Upper Santa Cruz Watershed are highly sensitive and by this nature can easily produce abrupt changes in SESs. As evidence presented in chapters four through six documents, multiscalar political and economic changes—the workings of a regional and national political economy--dominate the history of the social components exemplified by San Lázaro. Because of the intersection of climate variability, climate sensitive flora, fickle hydrology, and multi-scale political-economic influences, the case study of San Lázaro fits the bill nicely, and can be used to at least tentatively evaluate resiliency theory, particularly as it might be applied to the study arid political ecologies and the Northwestern Mexican countryside.

Overview of the Dissertation

Chapter One allows me to establish the major threads of this dissertation project and build a case for how-and why-they fit together. These threads revolve around a central question: how have national-level changes in Mexican tenure changed irrigation water and rangeland management in San Lázaro, Sonora, and what are the consequences of these changes for the landscape controlled by the community? Threads central to this discussion include the ecology of agropastoralism, environmental variability, recent political economic history of Mexico, and environmental history in the Santa Cruz area. I will use this chapter to introduce how political ecology can be advanced by this case study by applying new ecological theory from non-equilibrium systems and insights from recent watershed management discourses.

Chapter Two describes the setting for the story of San Lázaro and illustrates why making a living in this area is such a challenge-particularly with regard to extreme environmental variability. It also describes the Upper Santa Cruz Watershed in which San Lázaro sits, in order to build a realistic and manageable context for the ecosystems and political economies subsequently described. In so doing, this chapter characterizes the natural capital of the watershed and the case study community of San Lázaro.

Chapter Three discusses how political ecology and the new ecological theory from both non-equilibrium systems and recent watershed management discourse may be usefully applied to the analysis of arid land ranching and agriculture in the Upper Santa Cruz River Watershed. Also within Chapter Three, I will also describe theoretical contributions of scholars working on cyclic change in social-ecological systems and how these can be evaluated using the history of land use, climate variability, and cross-scalar political economic transformation (referred to as panarchical phenomena). Of particular utility here is the concept of the adaptive cycle (Holling 2001) which will be evaluated throughout this research project.

"Panarchical" transformation as studied by Walker (2006), Gunderson and Hollings (2002) and others is a long-term process. As such, use of the framework necessitates understanding the build up and exploitation of natural capital over time by SESs. This requisite depth of field closely follows the approach of historical ecologists (e.g., Crumley 1994). Chapter Four discusses the early and more recent environmental history of San Lázaro and in so doing builds a case for the difficulties of natural resource management outlined in subsequent chapters. The long-term impacts of human settlement and land use cannot be ignored within the context of the watershed and so this chapter will establish the historical ecology of the community and its problems of resource management.

More recently, the case study community of San Lázaro was radically transformed into a sort of agrarian utopia--the ejido--by government and household-level interaction. After years of single owner management, the ranch became the site of new forms of social experimentation and intense ecological exploitation. Chapter Five describes the heyday of the ejido economic and ecological management regime in San Lázaro. It places the ejido's management into a wider political economic context of Mexican state-driven development and describes how that system was corrupted by internal systems of management. This local and regional-level corruption resulted in mismanagement of range and water resources. What followed was a period of adjustment of the SES.

The most important adjustment of the SES involved tenure and therefore, access to range, water and agricultural resources. In Chapter Six, I discuss at length the transformation of the ejido system from corporate to private management of natural resources including rangeland and water. In it, I describe the community's reactions to neoliberal restructuring. These reactions include the growth of freehold leasing and off-farm livelihood strategies, as well as the capture of the community by the global narcoeconomy described in Chapter Seven. The elites created in this covert economy establish a new economic order in San Lázaro and elsewhere along the border that fits smallholder households into a globalized political economy. Lastly, I take this opportunity to discuss the environmental ramifications of that new covert political economy.

In the final chapter I attempt to place the community within wider trends of development along the U.S.-Mexico border and draw some conclusions about the past, present and future of San Lázaro and its watershed. I will also use this chapter to bring together the threads of physical environment, theory, and economic practice at the watershed-level that were described in previous chapters.

Returning to the theoretical problems in this dissertation, I address how smallholders in this environment face a persistent dilemma with regard to their management of the desert-grassland ecosystem and exceptionally variable river basin hydrology. Drawing on new rangeland ecology theory, I attempt to demonstrate the lack of fit between state-centered and neoliberal logics with this type of environment. Utilizing the case study of San Lázaro, I will advance my central critique of contemporary cultural and political ecological models, building the case for utilizing new ecological models—adaptive cycles, states and transitions--for arid land ecology within the social sciences.

A Note on the Methods

This research was conducted using a mixed method strategy. Prior to entering the field, I conducted research into secondary sources and prior research to understand the nature of the problems facing arid land ejidos, neoliberalism, the U.S.-Mexican border and the study area of the Upper Santa Cruz River Watershed. Beginning in 1999, while working for the Sonoran Institute I became aware of the absence of research on this reach of the Santa Cruz River and its surrounding communities. While working for the Institute, I also had the opportunity to engage in participant observation as part of the non-governmental organization, which is an important actor in the watershed, and the community of San Lázaro. I will address this organization in Chapter Six.

While in the field (spring 2002-fall 2003), a majority of my first three months was spent getting to know the community through personal interactions and active participant observation in fiestas, rodeos, baseball games and other community events. Once I was familiar with the community and its social make-up, I began gathering a series of oral histories of the oldest community members who could draw on memories of the town's environmental and political economic history since or before its founding as a formal ejido. The ages of these elders ranged from 80 to 47 years. In all, I recorded 15 of these histories over the course of the two-year field period. The shortest of these interviews went for little more than 30 minutes while the longest lasted for three hours over two days. I also engaged in guided and informal ethnographic interviews with strategic members of the community who could provide information on agriculture, ranching, and water management. These four interviews included the cattle boss who was in charge of maintaining official cattle censuses, the chief water judge in charge of the irrigation system, the former ejido president and current ejido president in 2003. With the cooperation of these key informants, I also conducted ranking exercises with three key informants—all active farmers and ranchers—to assess risk in farming and ranching activities. The survey instrument I utilized to assess risk is included in Appendix A. I also spent many hours discussing economics, culture, and resource management issues with my hosts--and eventually compadres, Alfonso Gonzalez

Siquieros and his wife Diana Marcela Bernal Cruz. Lastly, in the spring of 2006, I interviewed Joaquin Murrieta-Saldivar who was not only my compradre's boss, but also responsible for bringing the U.S.-based non-governmental organization the Sonoran Institute into play in the Mexican community. In all, I conducted 32 ethnographic interviews with various officials and community members over the course of three years. With the exception of key individuals working in their official capacities, the names of community members were changed to protect their anonymity.

With the assistance of secondary school students and two instructors, I conducted a household survey of the community, capturing data on livelihoods, overall community economics, perceptions of the environment, and basic demographics (N=69). These survey results—completed in April of 2003—were augmented by data gathered from the Instituto Nacional de Estadistica, Geografia e Informatica (INEGI) at the state, *municipio* (county), and regional level. Data from the 49 question community survey were hand tabulated by the author, used for descriptive statistics, and are presented within the body of this document. The survey is included in Appendix B.

In the summers of 2001 and 2002, I traveled to Hermosillo, Nogales, and Phoenix to gather environmental and historical data on the watershed from the offices of the Comisión Nacional de Agua (National Water Commission), the Comisión de Agua Potable y Alcantarillado del Estado de Sonora (Commission for Potable Water and Sewerage of Sonora), and the offices of the Arizona Department of Water Resources, which contains some data on the Mexican Santa Cruz. I also traveled to the Hermosillo, Magdalena, and

Nogales offices of the Mexican Federal Agricultural Ministry and the local state offices known as Fomento Ganadero del Estado de Sonora (Cattle Ranching Development of the State of Sonora). At these official government offices, I gathered hydrologic, climatic, water rights and other land management data for the Upper Santa Cruz Watershed. I also interviewed seven key officials on matters of water and land management.

Lastly, I gathered archival material on the San Lázaro and Upper Santa Cruz region through searches in the databases and collections of the University of Arizona, Arizona Historical Society, and State of Arizona Archives. These data were incorporated into the early environmental and political economic history. My research also included some analysis of selected environmental data, including range and riparian plant community condition as measured by species composition; climate variability as measured by rainfall patterns and stream baseflow conditions; fluvial geomorphology as measured by scouring floods, baseflow conditions, and channel cross-sections; piezometry of selected areas of the Santa Cruz.

Sources of contemporary environmental data included: INEGI, the Departamento de Investigaciones en Cíencias y Tecnología de la Universidad de Sonora, the Sonoran Institute, the United States Geological Survey, and the Arizona Remote Sensing Center. Climatological data were derived from the National Weather Service/National Oceanic and Atmospheric Administration (NWS/NOAA) and processed by my colleague Dr. Michael Crimmins of the Climate Science Applications Program of the University of Arizona for use in this research.

CHAPTER TWO: PHYSICAL SETTING AND ENVIRONMENT

Introduction

When viewed through the lens of contemporary Resiliency Theory (Walker et al. 2006), the story of environmental change in the upper Santa Cruz River Watershed is more than the sum of various environmental and social interactions typified by the case study of San Lázaro. Rather, it reflects a series of cycles of accumulation and exploitation of capital by various societies or even iterations of those societies in the watershed. Term I use here is not the traditional use of financial, social or political capital but what some ecological economists (e.g. Daly 2004; Costanza 1997; Folke et al. 1994) distinguish as “natural capital”, meant to signify the fruits of ecological processes (or the processes themselves) upon which human economic development depends. Implicit in this use of natural capital is that humans must ultimately develop both behaviors and technologies that support continued capacity for the environment to generate or maintain those processes or their outputs (natural resources). But this requirement ensures that humans observe the bounds set by the functioning of the natural environment to support human activities at various scales (Folke et al. 1994: 5). As we will explore in subsequent chapters, denizens of the watershed have not had an easy time accurately observing these boundaries, nor have those living in the watershed been able predict changes in threshold positions.

Since the 18th century, much of this capital is exploited to generate food through agricultural activities—mainly by extensive ranching. In the Upper Santa Cruz Watershed, these include soil formation and maintenance, predictable hydrologic cycling, regular precipitation, sediment transport, the maintenance of nutritious rangeland vegetation for livestock or wildlife. Much of this chapter will present an inventory of ecological processes and natural resources upon which a ranching livelihood depends. These processes and products roughly fall into four categories: climatic, hydrologic, geomorphologic/pedologic, and biotic. The inventory fills an important niche for understanding the historical and contemporary dialectic of cycles of accumulation and exploitation in the watershed. In short, one cannot characterize the political economic side of a political ecological call-and-response without a thorough understanding of the ecological variables in play.

Geography of San Lázaro, Sonora

Ejido Miguel Hidalgo, otherwise called San Lázaro by the locals, is a small town of 142 households, about 25 miles from the U.S.-Mexican border. In its peak, the ejido supported thousands of cattle, 200 hectares of farmland, and a thriving community of 1,500 people. The community sits along the southernmost reach of the Santa Cruz River, in the state of Sonora, Mexico. It is approximately 11 miles from the northern border and at least an hour travel time to the largest towns in the area-Nogales and Cananea that sit to the west and east, respectively (see Map 1). Most people living in San Lázaro are members of Ejido Miguel Hidalgo. Only about 40 percent of the ejido lands, however, lie within the Upper Santa Cruz Watershed. The remainder lies within the río Cocospera watershed, a tributary of the Río Sonora (Gray, Briggs and Murrieta 1998).

San Lázaro not only sits within a particular political economy but also a distinct landscape--in this case, the Upper Santa Cruz Watershed. The Santa Cruz River itself is perhaps the most important feature of San Lázaro's landscape. Like limiting factors in any ecosystem, the availability of fresh water in the river determines the livelihoods of the San Lazareños as well as their upstream and downstream neighbors. The Santa Cruz River begins about 20 miles upstream from the ejido in the Canelo Hills of the San Rafael Valley, and flows due south until it reaches the neighboring community of Santa Cruz. A slight bend in the river just south of this town-the municipal capital or cabacera-sends the river southeast into San Lázaro. The river flows nearly due east as it reaches San Lázaro, where it waters a floodplain clothed in rich riparian forest dominated by Fremont cottonwood, Goodding willows, hackberries, velvet mesquite, Arizona ash and seep willow. Just two miles after the river leaves San Lázaro, it becomes largely subterranean as it hits pockets of deep Holocene alluvium. Once outside the ejido, the Santa Cruz River becomes what hydrologists classify as intermittent-flowing superficially only when rainfall or snowmelt is sufficient. The San Lázaro reach of the river is therefore the end of last perennial stretch of stream flow in modern times.

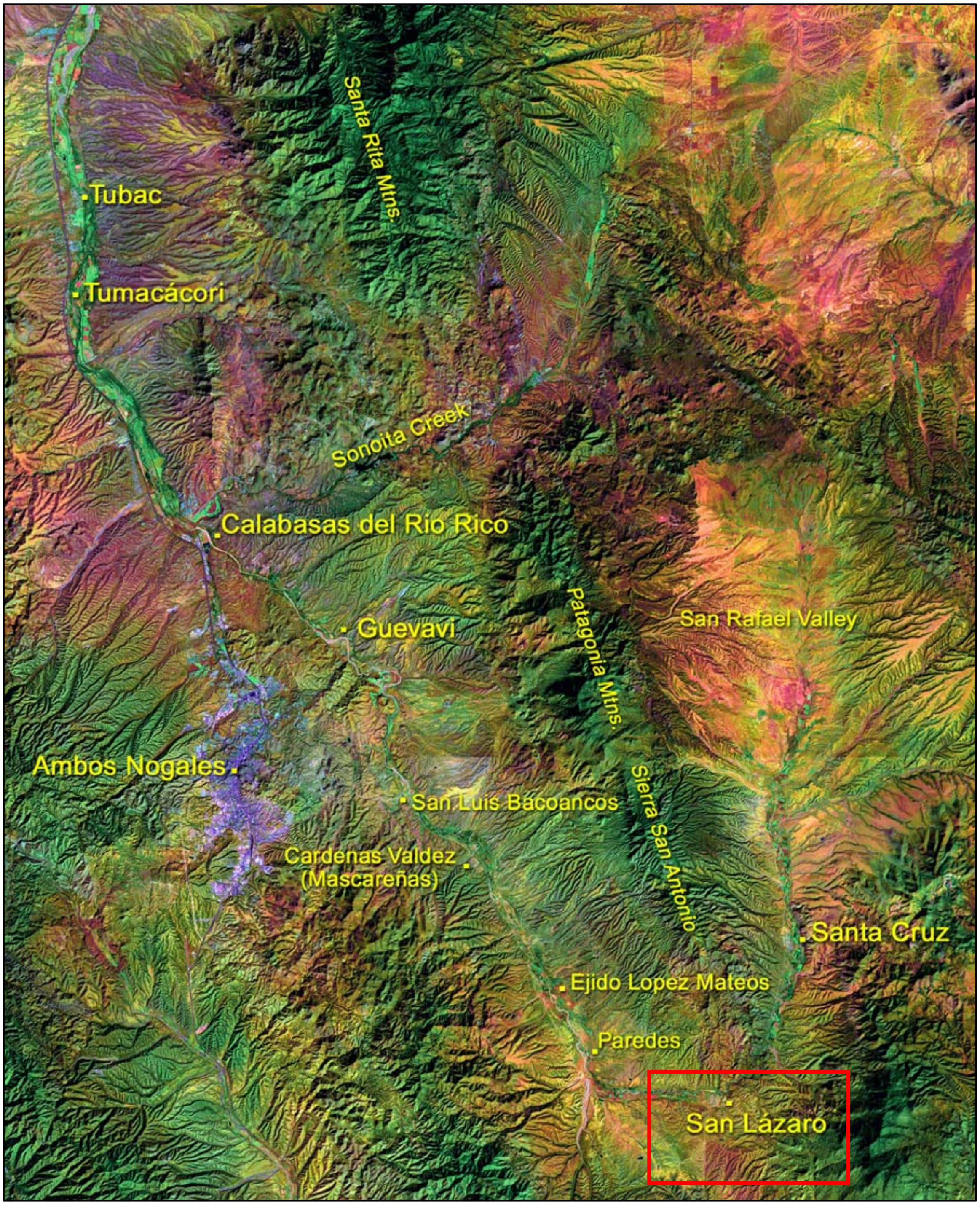


Figure 2.1. The Upper Santa Cruz Watershed including principle population centers. Adapted from false-color Thematic Mapper image (Dohrewend et al., 1999).

Northeast of San Lázaro, the river continues through a diverse physical and cultural landscape. This stretch represents a river undergoing a mixture of largely anthropogenic hydrologic changes, some positive and some with negative repercussions for riparian ecosystems as well as the different societies that are dependent upon them for "ecosystem services." In hand with these ecosystem transformations, the communities within this reach of the river, known as the Pimería Alta, have changed dramatically as well. Spanish frontier towns such as Guevavi, Calabasas, Tumacácori and Tubac (the latter four now in Arizona) have alternated between heavy use by missionaries and indigenous populations in the 18th century, to abandonment during the Apache wars of the late 18th and middle 19th centuries, finally undergoing a transformation as 19th and 20th century cattle ranches, farming towns, retirement or artist developments, and historic parks. The Mexican and Anglo-period town of Nogales has also sprung up from the banks of the upper Santa Cruz, and functions as the base for capitalist development in this section of the watershed. The intertwined stories of these communities represent the story of the river's transformation by human societies dependent upon it.

Land use in the river basin has undergone dramatic changes in the recent past. This has been well documented from the entry of Spanish missionaries into the area in the late 17th century to present. At the same time, national and local-level political institutions have also shifted in equally dramatic ways. These institutional changes have been accompanied by transformations in how the local economy of the upper Santa Cruz has articulated within national and international political economies. Since European encroachment on Northern Pima Indian riverine communities, the Santa Cruz River has been transformed from the basis for a peripheral Spanish Imperial frontier economy to a zone of light Mexican colonization and natural resource extraction, to a stream divided between communities of the modern industrial border states of Arizona and Sonora. In its present form, the Santa Cruz River now represents a hotly contested ecological resource for real-estate development, domestic use in neighborhoods of Nogales, sewage treatment, and international industries.

Like many areas of a region loosely designated *la frontera*, the Upper Santa Cruz Watershed encompasses extraordinary biodiversity in both floristic and faunistic senses of the word. Like other desert rivers such as the nearby San Pedro River, forested riparian corridors along the Santa Cruz River allow charismatic megafauna such as black bear, bob cat, mountain lion, and-in historic times-grizzly bears, jaguar and wolves, to move through the desert from north to south. The Santa Cruz is also critical watering, nesting and food resource on one of the last intact flyways for bird species migrating between Mesoamerica and North America. In this region, it is one of only three major streams that cross the international boundary. Lastly, the Santa Cruz represents one of the few remaining free-flowing streams in the binational region, fed by a bimodal pattern of summer monsoonal and winter frontal precipitation, averaging less than 18 inches total for the year.

The upper Santa Cruz is the center of a cultural landscape that persists in the face of rapid social, political, and economic change. Small farming and ranching operations still exist within the basin. Some of these agropastoralists (mainly those in Mexico) still utilize water diversion technologies developed in the late 18th century and also continue to use some of their original political institutions for water control. Similar to the *acequia* culture in the Northern Rio Grande watershed of New Mexico and Southern Colorado (cf. Rivera 1998), farmers along portions of the river stretching from Lochiel, Sonora to Ejido Miguel Hidalgo, Sonora use communal labor and local leadership hierarchies (*mayordormía*) to maintain equitable surface water irrigation flows to their communities (Sheridan 1988). In along other stretches of the river--particularly near Mascareñas Ranch--large landholders still control vast areas of the watershed, in much the same way that large commercial cattle ranches controlled these areas in the 19th century. This type of cultural landscape persists, even in the face of government seizures and the formation of corporate agrarian ejidos-many of which eventually failed-leaving the original heirs to continue to run cattle on their range.

On the other hand, because the Santa Cruz River runs through the international boundary between Mexico and the United States, pressures that are unique to that border are transforming it. Specifically, the river basin is being impacted by new economic dynamics of globalization, largely since the initiation of the North American Free Trade Agreement in 1994. The twin cities of Nogales, Sonora and Nogales, Arizona (hereafter referred to as Ambos Nogales) are currently experiencing a demographic explosion-especially the Mexican half of the urban area-as migrants from interior Mexico seek work in the border zone (the population has increased from 84,000 in 1980 to 159,103 in 2000). Symptomatic of the aging of the United States population, the area between Nogales and Tubac, Arizona has become a hot spot for retirement home development, augmenting the in-migration of bluecollar workers attracted into the area to work in new border industries. The consequence of population growth is more urban demand for water and urbanization of historically rural areas. Both cities presently extract roughly 50 percent of their potable water supplies from the Santa Cruz River (Morehouse, Carter, and Sprouse 2000). Water quality is also taxed by local industrial or domestic expansion, as witnessed by dramatic internationally financed measures such as the Nogales International Waste Water Treatment Plant to deal with this issue (Ingram, Laney and Gillilan, 1995).

Hydrology, Geology, and Soils

The Santa Cruz River has several hydrogeologic characteristics that are important to note here because they profoundly impact the story of human settlement and land use in the San Lázaro area. The river is considered to be perennial from its headwaters through the town of Santa Cruz. From the town of Santa Cruz to San Lázaro the flows are more intermittent--and heavily dependent upon upstream use patterns, mountain front recharge in the spring, as well as episodic flood events due to summer and fall precipitation. Further downstream from San Lázaro, the river currently shows ephemeral behavior, with large subflows that rarely reach the surface except during peak flow events in the winter or summer rainy seasons. From its headwaters in the San Rafael Valley, Arizona, the Santa Cruz River heads south into Sonora, México, where it makes a 51-km U-turn before re-entering Arizona near Nogales. The elevation where the river crosses the border downstream of the San Rafael Valley is about 1,400 m, dropping to 1,128 m at the point where it returns to the U.S. near Nogales. Water flows pick up considerable momentum as they tumble through the rocky canyons upstream from the community. This means that at flood-stage, the river can exert a massive force on downstream areas. The river is fed by a dozen small and two large arroyos that can quickly transform from dry washes into raging torrents during rains. Upstream soil erosion may contribute to what hydrologists call the "friction potential" of the stream, resulting in floodwater will easily degrade stream banks, agricultural areas, bridges, and other elements of the human landscape while at the same time aggrading or building downstream landforms. Lastly, the alluvial deposits that hold groundwater in the Upper Santa Cruz Watershed are relatively shallow and narrowly pinched by topography, meaning that demand may potentially outgrow this source. Water in the alluvium is shallow, but not in large abundance.

Of equal importance to San Lazareños is the geology of the river bottom. A highly transmissive alluvium, meaning it absorbs precipitation or surface water easily, characterizes the river bottom (Nelson and Erwin 2001: 14). This layer-cake of rock, sand and water is also quite shallow; consequently rains can quickly augment surface flows. This shallowness also means that the subsurface water also be easily perforated or tapped by wells. Although the shallow aquifer (over a mile wide and 100 feet deep at Paredes) is easily tapped for subsurface flows, because surface flows are intimately linked to the subsurface flow of water in the alluvium then stream water levels will drop quickly. Overall, this results in a river that is highly sensitive to both precipitation and groundwater pumping.

The Santa Cruz River in and around San Lázaro has carved a broad channel in parts of its course, scouring the substrate down to cobble, large deposits of course material and boulders. These areas are wooded with dense stands of Fremont cottonwoods (*Populus fremontii*), Goodding willows (*Salix gooddingi*), seep willows (*Baccharis salicifolia*) and herbaceous plants. Intact riparian plant communities along the Sonoran reach of the river include cottonwoods, willows, sycamore (*Platanus wrightii*), Arizona ash (*Fraxinus velutina*), mesquite (*Prosopis velutina*), hackberry (*Celtis reticulata*), and walnut (*Juglans major*). Covering approximately 1,578 ha, the riparian zone is thought to be particularly important for migratory birds. An initial two-day survey recorded 59 species of birds with a total of 793 individuals identified (Gray, Briggs, Murrieta 1998). Much of the northern portion of the river in Sonora is perennial, providing habitat for at least four native fish species, including the threatened Gila topminnow (*Poeciliopsis occidentalis occidentalis*).

In the reach of the Santa Cruz immediately northeast of the town center, the river has created a broad, alluvial floodplain dominated by three layers of recently formed terraces above the river channel itself. As I will describe in the subsequent chapters, these historic floodplains are vital for agricultural activity by the community. On these terraces, community members have traditionally cultivated cash crops such as apples and winter vegetables, pasture for livestock and alfalfa, barley, and hay production for cattle.

The terraces provide critical pockets of relatively deep, nutrient-rich soils in a region where most upland soils are generally poorly defined, rocky, and nutrient-limited. Because of these characteristics, hydrologic capacity and infiltration rates in these upland soils are often quite low--meaning that sans vegetation, water from strong precipitation events runs off the surface and there is generally little storage within these upland substrates. Historic floodplain soils that receive these flood flows, however, may store these flows for limited times depending upon compaction of the surface area (often influenced by grazing practices), impermeable surfaces (pavement, roadways, other human-made structures), and vegetation root densities.

Surface flow is the major contributor to water in xeric streams such as the Santa Cruz. In desert grasslands and oak savannahs, the average annual precipitation converted into subsurface contributions to stream flow is between 5 and 8 percent (Baker et al. 2004: 55), meaning that much of the precipitation is immediately converted into surface flows. Vegetation in these environments is sparse, soils are shallow and less permeable and high-intensity rainstorms frequently exceed infiltration capacities of soils, leading to greater overland flow. Furthermore transmission losses are high in dry stream banks and channel bottoms. In other words, it takes an unusually long or persistent precipitation event to yield long-term subflows that contribute to perennial flows. Secondarily, most water falling on watersheds such as the Upper Santa Cruz moves on quickly.

Surface and through flows into these bottomland areas therefore often contribute to rapid rises in the Santa Cruz River itself (see Figure 2.2 below). These bankfull events--so named because they result in the river reaching its average 1-3 year highest point before slopping on to surrounding floodplains are rapid during times of heavy rainfall in the watershed. During particularly fierce rainstorms, the river can rise quickly and move massive amounts of sediment from both the floodplains and the bed of the stream itself. This is typical of streams in the xeric Greater Southwest where sediment transport and storage is significantly higher than in more mesic systems. However, these flood events also recharge the floodplain's limited underground storage areas and contribute to long-term surface baseflow of the stream (baseflow being the amount of water left flowing in a stream during the driest part of the year). While the alluvium is estimated to be not much more than 100 feet in depth, (Halpenny & Halpenny 1991: 6) during wet years, baseflow supplied by these limited aquifers is significant even when it is reduced to a trickle in the long, hot days of May and June.

Floods are important events to the systems formed by intermittent, ephemeral or perennial streams. Streams in the U.S. Southwest and northwest Mexico tend to store and transport large quantities of sediment. The largest sediment loads are often transported during peak flows associated with high-intensity, short-duration rainfall events occurring during the summer and fall storm season. In ephemeral or intermittent streams, sediments build up in the channel bed (bedload sediment) and adjacent floodplains and then flushed during peak-flow events. The San Lázaro reach of the Santa Cruz behaves much like an intermittent stream, storing sediments in large floodplains that then degrade during floods. The flooding is a mixed blessing for human residents, resulting over the years in serious damage to the local economy and infrastructure, while at the same time providing enriched floodplain that then recharge floodwaters into shallow Holocene alluvium aquifers. These outcomes will be discussed in greater detail in subsequent chapters.

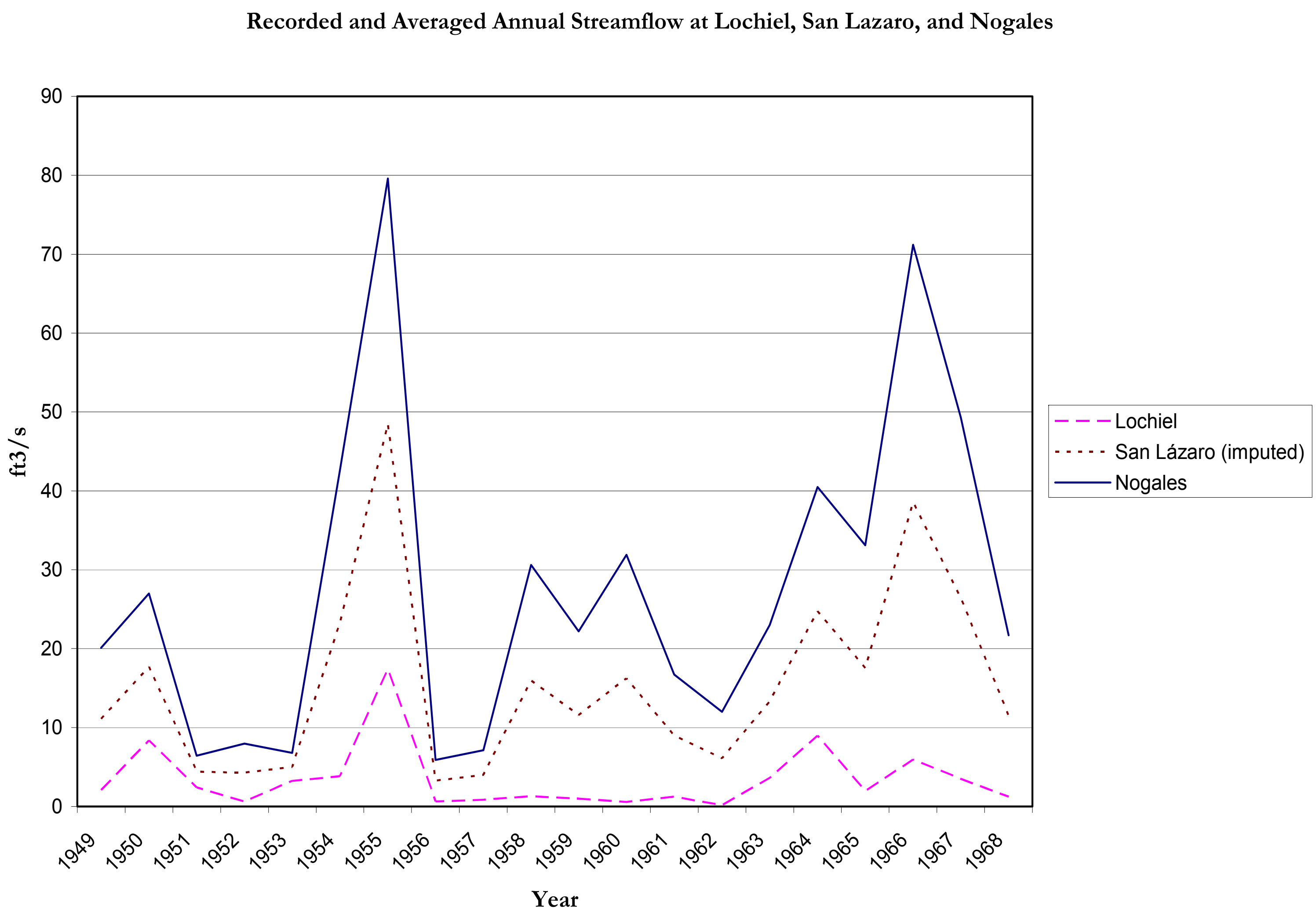


Figure 2.2. Annual streamflow for the Upper Santa Cruz as measured at United States Geologic Survey gauging stations located near Lochiel and Nogales, Arizona. Data for San Lázaro is calculated as an average of both points.

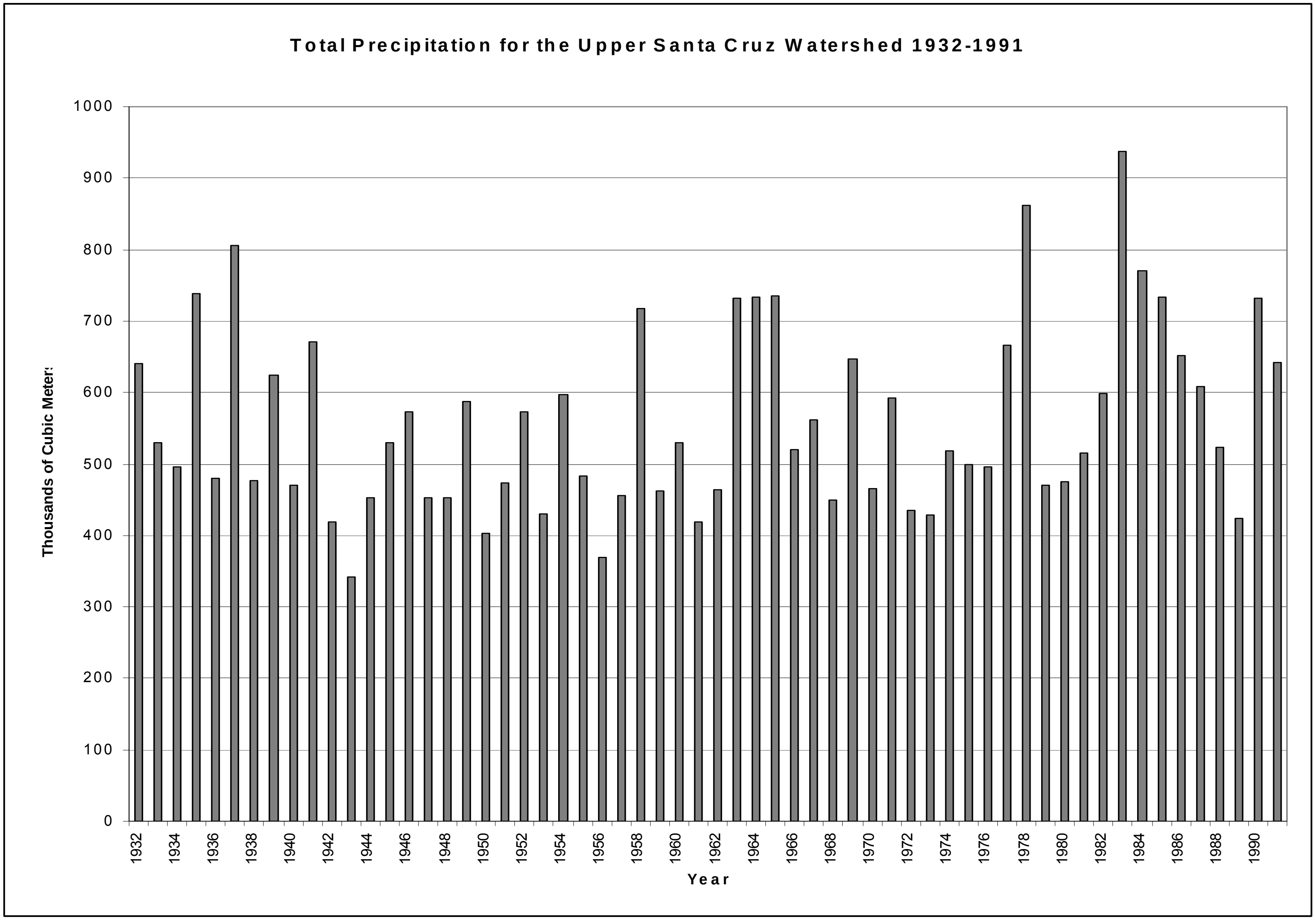


Figure 2.3. Total annual precipitation in the Upper Santa Cruz WatershedUpper Santa Cruz Watershed 1932-1991. Source: Cervera 1995.

Riparian vegetation growing along the channel and in the immediate floodplain plays an important role in the morphology and behavior of streams in the region. Tree, shrub and herb roots contribute to slowing the energy of peak flows, allowing trapped sediment to fall out of the water column and contribute to the width of the channel as well as its long-term stability. Riparian vegetation contributes to organic matter in the stream itself, often forming an important base for aquatic ecosystems. Large woody debris from riparian vegetation also helps to create morphological variety by capturing sediments, other debris, and slowing flows. In the Santa Cruz watershed, riparian vegetation is sporadically supported by the river, or has been altered by anthropogenic activities such as livestock grazing or removal for floodplain agriculture. The San Lázaro reach, however, supports a large and somewhat healthy variety of tree species, functional layering, and age-classes. Efforts by locals to restore the river's riparian vegetation are also a large contributor to these conditions although long-term patterns in the management of the river may lead to conflict with this goal (see subsequent chapters for more details).

The upland terraces and hills surrounding the main course of the river are covered with rocky soils and dominated by oak woodlands, mesquite *bosques* (woodlands), and open savannah grasslands (see subsequent sections below for a more thorough description of vegetation types in the watershed). At a higher elevation still, the savannahs give way to galleried forests of oak, Ponderosa pine, and wild walnut trees. These varied ecosystems provide abundant sources of food, moisture, and material for the human communities within them-as evidenced by at least 8,000 years of human occupation from archaic hunterforagers, Trincheras and Hohokam cultures, Spanish and modern Mexican communities. Since the introduction of cattle into the area in the middle 17th century (by Spaniard Jose Romo de Vivara) cattle ranching has become one of the most successful means of harvesting the primary productivity of these ecosystems. The great horse and livestock-culture of Northwest Mexico (Sheridan 1988) fits well into the Upper Santa Cruz Watershed.

Climate

Like most human activities, the natural environment strongly influenced the formation of the cattle ranching industry in San Lázaro, and the rest of northern Sonora. Given the value and limits of water, the most important natural influence is of course, climate. Ranching is a way of harnessing a highly diffuse form of ecological productivity, concentrating the primary production of grasses and forbs into the cells of the livestock itself. But that primary productivity in these semi-desert grasslands is almost entirely dependent upon precipitation. Without consistent precipitation, cattle ranching becomes much riskier, and agriculture on the Santa Cruz River floodplain becomes nearly impossible. Northwestern Mexico-and particularly Sonora-is generally an extremely xeric region with rare semi-tropical and temperate ecotones. Climate in the region is divided into four major periods, two wet and two dry (see Table 2.1 and Figure 2.3). These are the foresummer drought, the summer monsoon rains, the post-summer drought, and the winter rainy season.

Seasonal Precipitation Variations

The year begins with the establishment of a semi-permanent high-pressure zone over the region leading to a foresummer drought that generally lasts from the end of April to the end of June. With the foresummer drought, temperatures reach yearly highs and relatively humidity drops to annual lows. In the upper Santa Cruz River Watershed, the oak-woodland and semi-desert grasslands dry considerably, with ephemeral or annual vegetation seeding and dying, while perennial species retreat into dormancy. Active growth in grassland forage species will continue through the month of May if precipitation in the late winter is sufficient. If few storms deliver moisture late in the previous season, much of the grasslands surrounding the Santa Cruz will go dormant.

The foresummer drought is bracketed by two critical wet periods. The first-winter rainfall-is fickle in this region. On average, the low deserts surrounding the Colorado River and its delta receive less than 10 inches of rain a year. Most receive far fewer than this mean and the distribution of those rains is highly variable at best. Topography plays a major role in this climatic pattern. To the east of these dry deserts, the volcanic and fault-block mountains of the Sierra *Madre* (and more northerly *Madre*an Archipelago to the east of San Lázaro) rise to form a considerable topological barrier to the pacific frontal storms of the winter-*las equipatas*. Consequently, the western front of these ranges receives the benefit of increased precipitation as cool, moist air masses rise over them and drop their precious payload of moisture on the landscapes below. These rains may come anytime between November and April. Because they are often associated with Pacific cyclonic storms that attain very large sizes and cover much of the region with precipitation, delivery of the equipatas is often of low intensity (Webb, Betancourt et al. 1992). Consequently, even though summer rains constitute the bulk of precipitation that reaches the region, the winter rains are more widespread, with soaking rains at the lower elevations and snowfall in the mountainous areas. Precipitation is low to moderate intensity but may persist for several days (Sheppard, Comrie et al. 1999).

Jan.	Feb	Mar.	April	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1.15	0.90	0.92	0.36	0.24	0.50	4.46	4.20	1.59	1.42	.68	1.46	17.87

Table 2.1. Average precipitation totals per month. Source, National Climate Data Center.

After the foresummer drought, the summertime too, brings moist air to the region, with considerable rainfall-las aguas-falling across northern Sonora. The North American or Mexican monsoon as it's called is the major climatic feature distinguishing this region from the remainder of the continent. Rains generally begin in early July with a surge of moisture from the Gulf of California, possibly augmented by currents off of the Gulf of Mexico (ibid.). Because of greater adiabatic heating along the western mountain fronts of the Sierra *Madre* or *Madre*an Archipelago, the western slopes again receive greater amounts of precipitation than the deserts to the west. Summer rains are intense and highly variable in temporal and spatial scales. One part of the region may receive several inches of rain in a matter of hours while a few miles away the desert will remain as dry as it was in June.

The intensity of summer rains is important hydrologically. With higher rainfalls over shorter periods, soils that cannot accommodate high infiltration rates will see dramatically increased runoff rates. As infiltration is further impacted by land-use, runoff during monsoonal rains only increases. Low infiltration during these monsoon events means that aquifers and surface systems are often only temporarily affected by the increase in moisture, especially when that moisture is largely concentrated as surface runoff. The result is that the summer rainy season, while important, does not bring long-term stability to hydrologic regimes in the region. Temporary surface moisture will bring out ephemerals, some increased growth in perennial grasses and forbs, but generally these are secondary to the impacts of deeper soakings from winter precipitation.

During and after the summer rains the region is also often the recipient of tropical low pressure systems that move in from the Gulf of Mexico or the Pacific Ocean. These storms produce torrential rains and strong winds, producing great economic damage to Sonoran infrastructure, while at the same time contributing significantly to rainfall totals. In the last four decades, tropical storms have resulted in major flood events on the Santa Cruz River and tributaries. Because rainfall totals are intense and short-lived, they have less long-term impact on local aquifers and therefore sustained baseflows in the river itself.

The Upper Santa Cruz Watershed falls into the broad transition zone between low western deserts with sparse precipitation and the cooler, moister *Madre*an landscape. Median precipitation is approximately 17 inches at a given point or 560 thousand cubic meters falling throughout the entire upper watershed per year. This is only a median, however, and like much of the region, precipitation is quite variable both spatially during summer rains and temporally for las equipatas in the winter (see Figure 1, above). Any productive agricultural activity in the area must depend upon either native vegetation that is well adapted to this rainfall regime, or draw on aquifers or groundwater supplies to irrigate.

Vegetation

Native vegetation in the Upper Santa Cruz Watershed is well suited to this climate regime and underpins the productivity of the entire basin from an ecological standpoint. As I noted earlier, that ecological productivity is transformed through cattle grazing into economic productivity for the *ejidatarios*. The implications of what grows where and how well are also important for watershed health--a point I will get to later in this chapter. Furthermore, the ecological dynamism of the watershed is usually described by the composition and successional stage of plant communities in it. Understanding this will allow us to make decisions about what models for these dynamics are most appropriate.

The watershed sits in a transition zone between the *Madre*an Archipelago dominated by oak woodlands (known commonly and as *encinal*) and semidesert short-grass prairies unique in the region (Brown 1994). The *encinal* and montane coniferous forests extend up from the Sierra *Madre* to the south, while the shortgrass prairie and semidesert grasslands are remnants of ecosystems that once extended from the Great Basin into southeastern Arizona. In some areas of the watershed, particularly on zones above 1,300 meters, the *encinal* blends with the semidesert grasslands to form open oak savannahs and grama grass (*Bouteloua* spp.)—mixed grass-mixed shrub grasslands. Lowlands in the watershed (below 1,300 meters) are dominated by Mesquite bosques and-with sufficient moisture-galleried riparian forests. The richness and variety of these plant communities belies little of the challenging environments in which they are found, with wild swings in temperature and moisture regimes. We will begin the floristic tour of the watershed at the highest elevations and work to the lowest.

Starting in the higher elevations above 1500 meters, Mexican oak-pine woodland occurs between 2,210 and 1,500 meters depending upon exposure, interspersed with pure stands of oak or pine at either ends of the elevation range. The dominant species of oaks in the Santa Cruz watershed include the common Emory Oak or *bellota* (*Quercus emoryi*), the Arizona White Oak (*Q. arizonica*), and the Mexican Blue Oak (*Q. oblongifolia*). Less common but still incident in these oak woodlands and savannahs are the Gray Oak (*Q. grisea*) as well as the more tropical *Quercus albocincta*. Conifers in the watershed include the Apache Pine (*Pinus engelmannii*), Chihuahua Pine (*P. leiophylla*), Arizona Pine (*P. ponderosa var. arizonica*), and more rarely, Pino Triste (*P. lumholtzii*) (Brown 1994). Arizona Cypress (*Cupressus arizonica*) and Alligator-bark Juniper (*Juniperus deppeana*), Mexican Pinyon Pine (*Pinus cembroides*) as well as Madroño (*Arbutus arizonica*) complete the common subdominant trees of these woodlands. Other common subdominant plants include Beargrass (*Nolina microcarpa*), Desert Spoon (*Dasylirion wheeleri*), and Sideoats Grama (*Bouteloua curtipendula*).

Soils make the difference between the occurrence of the encinal and the open savannahs or semidesert grasslands that characterize much of the watershed. On thinly profiled or rocky hillsides encinal will dominate, while deeper soils in the bottomland and in the alluvial floodplains results in vegetation of the grassland type (ibid.). In places where grazing has been particularly intense, or where soils have deteriorated because of erosion, mesquites (*Prosopsis velutina* and *P. glandulosa*) will tend to dominate the landscape, altering the occurrence of other plant communities that were previously common in the habitat type.

Large portions of the mid-elevations in the watershed are dominated by the Grama Grass (*Bouteloua* spp.)-Mixed Grass-Mixed Shrub Grassland. This is largely a Chihuahuan semi-desert grassland community dominated by perennial grasses and shrubs. Characteristic plant species include Fairy Duster (*Calliandra eriophylla*), Rabbit Brush (*Chrysothamnus nauseosus*), Hedgehog Cactus (*Echinocereus pectinatus*), Palmer Agave (*Agave palmeri*), Lehman Lovegrass (*Eragrostis lehmanniana*), and Blue Grama (*Bouteloua gracilis*). Lehman Lovegrass, a species introduced form South Africa, appears to be spreading naturally throughout much of the region to the detriment of more palatable native grasses. Arizona White Oak, Emory Oak and Honey Mesquite (*Prosopis glandulosa*) are scattered throughout the habitat.

The semidesert grasslands are the most important and unique feature of the Upper Santa Cruz River watershed, particularly in the vicinity of the headwaters as they course through the San Rafael Valley, Arizona and into the community of Santa Cruz, Sonora. The greatest plant diversity of this habitat type occurs in the grasses. These include the muhlys (*Muhlenbergia* spp.), Tobosa (*Hilaria mutica*), Curly Mesquite Grass (*Hilaria berlangeri*), Little Bluestem (*Schizachyrium scoparium*), Plains Lovegrass (*Eragrostis intermedia*), Blue Grama (*Bouteloua gracilis*), Sideoats Grama (*B. curtipendula*), Purple Three-Awn (*Aristida purpurea*), and Tanglehead (*Heteropogon contortus*) (Brown 1994). Invasive exotic Lehman Lovegrass has also made inroads into portions of this habitat. In areas with deep alluvial soils and a shallow water table, Sacaton (*Sporobolus wrightii*)-dominated communities often appear. Dry-tropic stem and leaf succulents are common in this habitat type, including Beargrass (*Nolina* spp.), Sotol (*Dasylirion wheeleri*), Yuccas (*Yucca elata*, *Y. schidigera*, *Y. schottii*), and Agaves (*A. parviflora*, *A. schottii*, *A. parryi*, *A. parryi* var. *huachucensis*). Several genera of cacti including *Opuntia*, *Ferocactus* and *Mamilaria* were also observed in the upper watershed.

Another unique and important habitat type in the watershed is the Sonoran riparian deciduous forest (Brown 1994). Riparian areas are delineated by saturated or semi-saturated soil characteristics and by vegetative communities that require free or unbound water (Ffolliott, Malchus B. Baker et al. 2004). This riparian area, paralleling the main channels of the Santa Cruz River and its major tributaries is the richest and most diverse of the habitat types in the Mexican portion of the watershed, containing at least 147 species of plants including 78 genera and 44 families (Solis-Garza and Briggs 2001). The most important of these are the principal over and understory species lending the galleried forest its characteristics, including Fremont Cottonwoods (*Populus fremontii*), Goodding Willows (*Salix gooddingii*), Seep Willows (*Baccharis salicifolia*), and Velvet Mesquite (*Prosopsis velutina*). Other trees and large shrubs found in the habitat include Arizona Sycamore (*Platanus wrightii*), Arizona Walnuts (*Juglans major* var. *arizonica*), Velvet Ash (*Fraxinus velutina*), Net-leaved Hackberry (*Celtis reticulata*), Desert Willow (*Chilopsis linearis*), and an occasional Tamarix (*Tamarix chinensis*). Other important shrubby plants in the riparian areas include Senecio douglassi, Rabbitbush (*Hymenoclea monogyra*), and Mimosa laxiflora (ibid. 77f). High levels of species richness is a key characteristic of these semi-tropical systems. Downstream at Tumacácori National Historical Park, some 414 plant, 8 fish, 7 amphibian, 15 reptile, 115 bird and 28 terrestrial mammal species were recorded in surveys made during the 2000 and 2003 field seasons (National Park Service official, personal communication, October 2003).

The riparian areas of the Upper Santa Cruz Watershed are critical for many reasons beyond the vegetative diversity. Rather, these habitats represent some of the last, largely-unaltered remnants of the most endangered ecosystem type in the Greater Southwest, including both the southwestern United States and northwestern Mexico (Hendrickson and Minckley 1985; Council 2002). This is particularly acute in the United States, where groundwater pumping, hydromodification, agricultural and urban development, as well as diversion have largely restricted functioning riparian ecosystems to a few, isolated locales. In Mexico, a similar trend is underway, particularly as urban populations increase exponentially at the expense of nearby ground and surface water resources. I will describe this situation as it applies to the Nogales region in greater detail in subsequent sections.

Due to the paucity of water in the landscape, riparian areas, with their shallow water tables, intermittent or perennial surface flows, and variety of vegetative cover are important breeding sites for a number of birds, amphibians, insects, herpetofauna, and mammals.

One estimate places the number of animal species utilizing riparian areas at over 80 percent and with at least 50 percent of those species as obligate to this habitat for their entire lifecycles (Chaney, Elmore et al. 1990). Of special biological importance, Sonoran riparian deciduous forest provides the most important flyways for neotropical migrant birds in western North America. A broad diversity of species move from Mesoamerica through Mexico and into their summertime breeding habitats by transiting along the riparian corridors, where food, cover and water are most available.

These areas constitute not just critical sites for biological diversity but also for ecological dynamism-where nutrients transported as sediment load are transferred between locations in the watershed. Though water is the critical factor for the success of most riparian plant species, as well as obligate or transient fauna, the transfer of energy through the watershed by ephemeral, intermittent, and perennial flows creates the conditions for constant environmental change. The movement and storage of sediments is critical to the health and stability of these systems, with episodic events such as peak flows acting as mechanisms for release, transport and deposition. The great diversity of plant and animal life is also a result of this state of flux and high concentration of nutrients into these "energy-sinks" in the landscape. For many obligate riparian plant species, disturbance is an important factor in plant community succession. Geomophorological uncertainty mirrors and often enhances the biological complexity of the habitat type with scouring floods, for example, bringing new recruitment to cottonwood and willow forests. Floodplain variation caused by peak flows also establishes unique microhabitats for animal and plant diversity (Briggs 1996; Baker 2004)

Riparian habitats also display internal variation. Several characterizations exist, including ephemeral washes, deeply incised canyons, braided channels, cienegas, and high-gradient headwater streams. The Santa Cruz River displays nearly all of these types in some form or another, although the most typical morphology of these habitats include a low-gradient stream bordered by willow-cottonwood dominated forest growing in the youngest alluvial deposits. These forests are then paralleled by a mesquite *bosque* (or woodland) occupying the older alluvium of the original dissected floodplains, especially those laid down at the confluence of major watercourses and their larger tributaries (these being typically ephemeral or intermittent in the Santa Cruz). These secondary floodplains are usually 1.5 to 6 meters higher than the current river channel (Baker 2004). Above the secondary floodplains, a scrub of smaller mesquites dominates the mesetas and eventually yields to either grassland or Oak savannah as soil moisture and soil depth declines.

Geology and land use combine to impact riparian vegetative communities in the watershed. The Sonoran-reach of the Santa Cruz River describes the river as it enters Mexico at Lochiel, Arizona in the southern end of the San Rafael Valley, flows approximately 60 kilometers (45 miles) through prominent geographic features such as the town of Santa Cruz, El Cajon (a *rancho* situated in a steep-sided canyon approximately 8 kilometers upstream from San Lázaro), the town of San Lázaro itself, Rancho Paredes approximately 10 kilometers downstream, Santa Barbara, Ejido Cardenas Valdez, Mascareñas, and Buenavista where the Santa Cruz flows north across the border (see Figure 2.1). Major tributaries of the river include ephemeral washes such as Parker Canyon, San Antonio, Cañada Ojo Zarco, Cañada Arizpe, Agua Zarca, Los Yaquis, El Mesquital, Las Pompas, and Los Alisos. While these water bodies are on the surface ephemeral-meaning they only flow during precipitation or runoff producing events, they support large assemblages of riparian growth and appear to exhibit water tables high enough to support this growth. In places where extraction of the river is severe (such as between Rancho Paredes and Buenavista, these confluences support the only healthy stands of Cottonwood-Willow-Baccharis spp. plant communities. Theses areas are also frequently sites of pre- and post-contact indigenous settlement and use of ridges or historic floodplains of the watershed (Mabry 2004). Present-day settlements are often concurrent with these areas because of increased surface and subterranean water.

Water Management in the Upper Santa Cruz Watershed

As witnessed by patterns of pre-historic, historic, and modern settlement patterns, as well as the biotic realities of life in a semi-arid land, river conditions are critical to the success of the watershed's human and non-human occupants alike. But river conditions have been an ever-changing phenomenon. The Santa Cruz River has gone through many hydrologic changes in the past 300 years of historic records. As recently as the middle 20th century, the river flowed intermittently along reaches as far north as Tucson and Marana, however, in its present state as a river besieged by groundwater pumping for urban and agricultural uses, it is largely dry between Rancho Paredes, Sonora-just east of San Lázaro-and Rio Rico Arizona, where it receives treated effluent from an international wastewater treatment plant servicing Nogales, Sonora and Nogales Arizona. This facility is the Nogales International Wastewater Treatment Plant.

The Santa Cruz has experienced some periods of climate-induced drought, but overall the 20th century has witnessed the greatest decline in flows thanks to an increasing demand from both an explosion of border-based industry and burgeoning urban population in the communities of Nogales, Sonora and Nogales, Arizona (see Table 1). Water supplies for the Mexican-portion of the city come from one of three sources-the largest being the Santa Cruz River between Paredes and the U.S.-Mexico border at Buenavista with 45 percent of the municipality's annual water budget. The other 50 percent is extracted from the neighboring Los Alisos basin as well as wells within the city itself-although these wells now extract subflows that may have connected to the Santa Cruz River via Potrero Creek. From this last leg on the Sonoran-reach, a total of 9,059 acre-feet of subterranean flows are extracted by wells combined with a large-capacity infiltration gallery (Morehouse, Carter et al. 2000). However, yields in this area of the Santa Cruz can decrease by more than 30 percent during dry seasons (Rodriguez Esteves and Gomez 1999).

Population Growth in Ambos Nogales		
Year	**Nogales, Son. Municipality**	**Nogales, AZ**
1890	1,200	1,500
1900	3,310	1,761
1910	3,856	3,514
1920	14,653	5,199
1930	15,605	6,006
1940	15,422	5,135
1950	26,016	6,153
1960	39,708	7,286
1970	53,494	8,946
1980	68,076	15,683
2000	159,103	20,878
2018 (projected)	344,988	27,000

Table 2.2. Population growth in Ambos Nogales (Nogales, Sonora and Nogales Arizona). Source: Morehouse, Carter and Sprouse 2000.

Furthermore, as Table 2.1 above illustrates, the Ambos Nogales area population is projected to steadily increase in the coming years. Planning documents compiled by INEGI and the municipality of Nogales estimate that the population will triple in the next two decades (Morehouse et al. 2000). Additionally, current official population figures only account for the survey of officially sanctioned residences, while the Mexican-portion of the city is characterized by the growth of unofficial colonias or improvised housing. Some estimates of the un-censused population add 40,000 to the official numbers for Nogales Sonora noted above. While industrial demand is the largest share of the Nogales water budget, the urban population's water use is the fastest increasing demand-side figure in the same water budget, using on the Mexican side an austere 39 gallons per person per day and the U.S.-side at over 200 gallons per person per day.

Irrigated agriculture also has also driven conversion of river water into a hotly contested commodity. Water demand for agriculture is highest in the reach between Lochiel and Paredes, with additional agriculture along the Santa Barbara to Buenavista reach. Agricultural water demand is heaviest in the vicinity of Santa Cruz and San Lázaro. Pumping in the Santa Cruz reach is so intense during the season of peak evapotranspiration (the foresummer drought in May through early July), that the reach west of San Lázaro often goes dry.

Investing or Expending Natural Capital?

The previous discussion should leave no doubt about the difficulties presented by physical environment in which the *ejidatarios* of San Lázaro find themselves. On the one hand, they are appointed stewards of a rich ecosystem with abundant resources for sustaining human life. On the other hand, *ejidatarios* are faced with extreme hydrologic variability and not far away, socially constructed vulnerabilities to these conditions. Climate, soils, vegetation and stream flows all vary sufficiently to make ranching and farming a complicated process that involves the understanding and careful balancing of different approaches. According to traditional cultural ecology logic and use and land tenure might reflect the vagaries of these conditions-at least under ideal conditions (Boserup 1965; Bentley 1987; Netting 1993). Ranchers would use common lands for the least productive, least intensive activities-extensive grazing-while the most fertile lands on the floodplain are used for intensive farming and specialized pasture for more economically remunerative activities (Sheridan 1988).

Land tenure in San Lázaro however, does not always follow this logic. Instead, it has been transformed over the years to become even more flexible at times, and at others, less adaptive to environmental conditions. This is largely due to historic statist, corporativist, and then neoliberal policy and economic signals from outside of the community that I will chronicle in chapters Four through Seven. The logic (or at times, ill-logic) of local land tenure and management reflect a mismatch between the scale of management of natural capital described and the scale of the ecological processes being managed (Cumming et al. 2006). This phenomenon shall be revisited in detail in the concluding chapter of the dissertation. The course of tenure and management change in the San Lázaro social-economic system (SES) also exposes a history of natural capital accumulation and exploitation, often driven by the scale mismatches I just alluded to.

Before we describe this sequence of cyclical events, it is important to look at the interplay of theories that should support this discussion. These theories—states and transitions, political ecology, resiliency theory—offer a critique of an important and common worldview that is based on stability and equilibrium. This scholarly and applied worldview limits the ability of both modern ecology and modern social sciences to properly analyze the flexibility and adaptations exhibited by local ranchers and others in San Lázaro, the Upper Santa Cruz Watershed, northern Sonora and elsewhere in arid regions of the world. The assumptions within it are, in fact, ossifying to the very behaviors and economic practices that must be applied for more successful management of arid and semi-arid rangelands.

CHAPTER THREE: CLEMENTS' CURSE: ECOLOGICAL EQUILIBRIA, PANARCHY AND POLITICAL ECOLOGY

*It was one of the hottest and driest years in living memory for the San Lazareños of Ejido Miguel Hidalgo. The rains were a month late, the temperatures well into the 100s in the hottest part of July, and the grass on the agostadero (rangeland) was reduced to brittle patches of unpalatable cellulose, a few a weedy annuals. Even the mesquites that dotted the hillsides were being stripped up to the highest reach of the hungry cattle. The Santa Cruz River that runs through the community was down to a mere trickle, and nothing more than brief mirage consisting of stagnant puddles downstream from the town. The acequia or canal system that ran through the community's agricultural floodplain was bone dry. Fields that had been ploughed early that month in expectation of summer rains-now looked dusty, raw, and barren. The drought had been dragging on for at least eight years. If the rains did not come soon, the ranchers would begin to kill their stock, starting with the sickest and concentrating what was left to the last green pastures in the high country. Already in March—months ahead of the usual season for "*pacas*"—ejidatarios had been purchasing expensive bales of alfalfa from Nogales and Magdalena for their animals, but money for this would soon run out. Things were indeed desperate in the summer of 2002. We fast forward to the middle of February of 2003. As cattle wander the town plaza, a community member tells me: "*es signo muy malo; indica que no hay pasto en los potreros cercanos*" (that's a bad sign; means that there is no grass in the nearest pastures). The heavily grazed rangeland had not recovered by this point, and rains were scarce thus far this winter. So, unless the rains fell consistently and heavily during the spring months, this looked to be another year of privation and desperation for those without the resources to purchase supplemental feed and a year of lowered profits for those with the extra financial reserves.*

What is so miraculous about this picture of economic hardship is that the community of San Lázaro and its contiguous ejido, Miguel Hidalgo, was once home to some of the richest rangelands in Northwestern Mexico and supported a prosperous farm along the banks of a deep and perennial reach of the Santa Cruz River. At its height, the ranch boasted year-round livestock numbers in the thousands (Sonnichsen 1974: 98). Prior to the 1960s, as the westernmost division of the Cananea Cattle Company under capitalist Colonel William Greene, lands now occupied by the ejido supported large cattle herds, abundant wildlife and championship thoroughbred horses pastured along the river. What happened in the ensuing years that have lead to these difficult circumstances? Why were rancher-farmers there struggling against such difficult environmental conditions in 2003? The answers lie in the unlucky confluence of several different factors--climate variability, Mexican agricultural policy, markets, smallholder tenure, and a century of significant environmental change in the rangelands of northern Mexico. Of these, the human variables--largely political economic in scope--are easiest to explain and to trace from their origins to their outcomes. On the other hand, the environmental factors--originating in different scales from global to microscopic--seem to lead to more unanswered questions and dead ends. Ultimately, it is these environmental variables that rule the decision-making, or at the very least, the choices of agropastoralists such as those in San Lázaro.

Theoretical approaches to agropastoralism are fraught with unknowns and inconsistencies. Scholars have attempted to understand how households and communities of agropastoralists--in the case of San Lázaro as elsewhere--make their decisions about where to graze, how many animals to sustain in a given season, and what may be best for the longevity of their rangelands (Fernandez and Allen-Diaz 1999; Westoby et al. 1989). Those working to apply their work more directly see the centrality of the problem being found in determining the proper stocking rates on a given rangeland and how can lessons from each case be generalized across landscapes, regions and other parts of the global grasslands (Scoones 1994: 14).

These approaches inevitably confront a central problem: that as the old Earth First! bumper-sticker says, "the Earth always bats last!" Because climates vary in arid lands (where most rangeland is found), soil moisture and other vegetation response are also variable. Human response to these conditions is therefore difficult to model. In other words, ecological relationships in rangelands do not always follow neat patterns that can be easily modeled nor accounted for as responses to local agropastoral practice, macro-level economics or extra-local policy. To relate cultural and political ecological approaches to the problematic ecological relationships, I will first deconstruct the models of human ecological behavior, and then discuss at length the old and new ecology of rangelands and watersheds. I will then attempt to build an acceptable model of the arid land ecology of agropastoralism in San Lázaro. This model will then underpin subsequent discussions of the community's response to changing social and environmental regimes. Finally, like a set of Matryoshka dolls, I will set this local-level model within the larger context of the “adaptive cycle” developed by Holling (2001) since that approach is ultimately being evaluated in application to the case study of San Lázaro, Sonora.

The Trouble with Ecological Approaches to Equilibrium

Less than a decade ago, a common assumption regarding "equilibria" dominated ecology and related, applied fields such as range management, forestry, as well as conservation biology. Based on the homeostasis models of Eugene Odum (1969), or the plant community succession models of Fredric L. Clements (1916), ecologists and others working in applied ecology fields, placed stock in the idea of equilibrium in ecosystems. That is, homeostatic systems by definition self-regulate and establish intra and inter-species equilibria between populations of organisms. The composition and direction of these relationships are easily elucidated but little understood, and difficult ultimately to assign definite causality. This paradigm is particularly well studied in relationships between primary producers and consumers, but also in terms of predator-prey relationships. Eugene Odum eventually applied this concept to evolutionary concerns--extending his theory to the thin metaphor of "strategy of ecosystem development" in which ecosystems somehow sought to self regulate and control nutrient cycles and species composition more and more as they gained age and adaptation to abiotic conditions. The common theme of these two influential theories of ecology was that of order. Ecosystems moved inevitably, argued both the earlier and post-war scientist, towards either a superaorganismal or supraorganizational order that resulted in measurable, attainable goals of climax or maturity (Worster 1993: 160).

The Clements model of succession and climax has been among the most influential theories in ecology, especially the applied ecology of range management. In the turn of the 20th century, one of the first American-trained ecologists by the name of Frederic H.

Clements devised a theory to account of changes in forest vegetation after a major disturbance such as fire, logging or floods. These changes appeared to follow an obvious order, starting with the establishment of the most basic plant life and moving in "seral stages" towards greater and greater organismal and ecosystem complexity. Forests, meadows, aquatic systems all seemed to respond to this graduated succession. Clements' 1918 model for ecosystem succession towards climax revolutionized ecological thinking for decades hence. It was useful because it was linear, easily correlated to biotic and abiotic factors (or drivers) and could be applied to a wide variety of ecological sites. Historian Donald Worster (1993: 158) essentialized the paradigm neatly:

> *Change upon change became the inescapable principle of Clements's science. Yet he also insisted stubbornly and vigorously on the notion that the natural landscape must eventually reach a vaguely final climax stage. Nature's course, he contended, is not an aimless wandering to and fro but a steady flow toward stability that can be exactly plotted by the scientist.*

The theory also has had important implications for shaping management of ecosystems, particularly as it applies to rangelands and forests. I will focus on the range management implications. Herbivory by livestock, for instance, maintained a vegetative community in a particular successional stage. The animals will differentially graze on vegetation, leading to favorable conditions for some grasses and forbs over others. Range managers sample the remaining species, calculate a density and composition, and come up with a prescription as to where the pasture sat on a successional-level. Removing or adding livestock would result in that pasture's species composition moving up or down the successional curve. Hence, range managers and livestock producers could "manage" the condition of their ranges by moving their animals around to different pastures and leaving grazed areas in a "subclimax" seral stage. Most importantly, pastures could be judged as "degraded" or in some form of "sustained yield" depending entirely on the successional stage.

Range management adapted this idea to grazing systems, implying that an herbivore-the cow-will graze climax species of highest palatability and leave behind a sub-climax ecosystem. Therefore, the balance ranchers should strive for includes a sub-climax community composed of palatable and less-palatable species. The carrying capacity of a particular rangeland was established as the point at which subclimax systems were established and below which climax plants would reestablish themselves. Livestock stocking numbers could therefore be established with some sense of certainty and a range was thereafter considered to be "well managed" from an administrative, economic, and ecological perspective. If pushed beyond this point of carrying capacity, the balance between grazing pressure and the inherent regenerative powers of the range was destroyed, and the condition of the range progressively deteriorated. The measurement of that process took the form of successively more disturbed plant communities and more basic successional species (Stoddard et al. 1975). The ecological balance would be easily restored to the rangeland ecosystem once the livestock were removed to another pasture (Behnke and Scoones 1993).

Much of the research for establishing these relationships, however, was conducted in temperate climates experiencing mesic precipitation. The equilibria implied in these ecological models did acknowledge environmental and concomitant ecological dynamics. At issue, however, was not that a stable equilibrium might not exist, but that it could be reestablished following disturbance-therefore showing ecosystem resilience, or that it could resist change in the face of disturbance (Sullivan 1996). Disturbance, according to some, is the key ingredient in arid systems where steady soil moisture and temperature are impossible to find, even in a good year. This, as Sullivan (1996: 4) writes, "is the antithesis of a non-equilibrium perspective which sees a wide range of variation as integral to dry land ecosystems, and has a positive view of such systems as displaying a remarkable degree of persistence in the face of stochastic abiotic events." Standard measures of carrying capacity in fact fail in an arid system where rainfall is highly erratic and where cattle numbers cannot predict herbivory results. We therefore must reexamine the concept altogether and attempt to salvage what is possible from it-given that any study predicated on the assessment of impacts must pick a point at which a system is deemed either "healthy" or "degraded," even if that chosen point is arbitrary.

Of course, another critical issue with this theoretical stance is that it under-girds the idea of sustainability, of ecological health, and of the concept of degradation. A northern temperate-zone “equilibrium-centered view of constant nature” provides a logical basis for the calculation of economic measures as the maximum sustained yield of a particular resource or landscape, and what are the limits for management strategies designed to maintain this. Even the equilibrium dynamics implied in General Systems Theory and steady-state systems thinking are used to identify negative feedback loops and so also for pin-pointing the causes for "healthy" or "unhealthy" ecosystem states (Jantsch 1980: 56).

Following this logic, the healthy state then becomes norm and any deviation from that arbitrarily selected baseline is therefore an example of "degradation" (Sullivan 1996).

Equilibria are difficult to measure or model in xeric or arid systems. Another significant mark against the application of the "equilibrium paradigm" to arid or semi-arid systems as identified by Sullivan (1996) and others (Behnke and Scoones 1993; de Leeuw and Tothill 1993; Fernandez and Allen-Diaz 1999; Briske 2003), is that it depends upon a model that includes a passive environmental system surrounding an active biotic system that is more or less closed. Disturbance--the interruption of that biotic system-- is the fulcrum on which ecosystem change rests. Equilibrium systems are assumed to return to their pre-disturbance state (i.e. homeostasis) or to their pre-disturbance trajectory (homeorhesis). Arid lands are anything but passive-as any rancher of them can attest. While temperate or mesic systems are usually limited by nutrients, a factor often controlled by the biotic, arid systems are most limited by moisture, a factor that is exclusively controlled by the abiotic portions of the system. Climate variability is an active ingredient in environmental change and ecosystem response to arid environments.

If variability is the key ingredient in dry land systems then relationships are non-linear and not easily predictable. This is particularly true for the deserts, riparian areas, semi-arid grasslands and *encinals* (oak woodlands) described in detail in the previous chapter. Precipitation, flooding and near constant change frame the context for biotic systems-especially the first. As (Illius and O'Connor 2000) point out, temporally and spatially irregular rainfall drive the plant communities of the ecosystem, preventing the species community from reaching a so-called "stable state" where average densities are the norm. Instead, the entire system is governed by erratic and periodic moisture, therefore playing a leading role in biological productivity. With nearly half or more of the yearly moisture coming from temporally and spatially variable summer rains, and the other half from generally quixotic winter storms, the moisture component is certainly the most limited for life in northwestern Mexico. In fact, the patterns of climatic variability are less understood in this region than in any other portion of the Western Hemisphere (hence, the current intensive study of the North American Monsoon via North American Monsoon Experiment). And any rancher, farmer, or urban water provider can attest to the difficulty in predicting the presence, duration, and effectiveness of rains on a specific piece of land-such as a pasture, floodplain, or watershed. The most important lesson here is that ecosystem properties in dry lands are driven by dynamic and non-linear interactions both within the biotic system (herbivores and forage plants, for example), and between the biotic system and its active environment (Jantsch 1980: 24).

Carrying Capacity and Sustainability in Rangeland Ecosystems

Carrying capacity as a concept is far from fixed in biological wisdom. In fact, much of the traditional theory and practice relating to rangeland carrying capacity is based on an economic model as much as an ecological one. Carrying capacity, therefore, is most heavily influenced by perturbations in political economy as much as changes in environment. It is the fulcrum at which the two meet-thereby grounding ecology firmly in political ecology. It is also a concept that is thoroughly imbedded in cultural and cultural economic perceptions of the livestock production, rangelands, and risk.

Much confusion arises around the concept of carrying capacity and the role of stress. For the theoretical biologist it is the number of organisms that can survive in a given environment at maximum stress before perishing. Organisms can still reproduce, but none are healthy. Carrying capacity in this sense is signified by the term "K" and is asymptotic to the point of no return for a particular population (Bartels et al. 1993). The range manager, on the other hand, defines carrying capacity by his or her economic needs-usually to produce animals that are healthy in the sense of producing the maximum of a particular animal-produced resource (beef, blood, wool, hides, etc.). The verge of starvation and anti-mortem stress is generally not the goal. On another, related tack, wildlife managers view carrying capacity as the ability for a landscape to produce animals that are healthy, reproducing, and where conditions are suitable for longevity of the ecosystem upon which those animals depend (Scoones 1994). This last perspective is perhaps the most moderate in that it takes into account the idea that starving, stressed animals are not the best management goal, while defining the process solely in terms of production is not always the best from an ecological point of view.

For purposes of this study, perhaps the most important, though equally confusing perspective on carrying capacity is that it is forever a moving target in terms of the economic goals of the individuals using it. Figure 3.1 below, illustrates the relationship between the hypothetical economic goals of an agropastoralist to the ecological conditions of the rangeland they he/she utilizes. The idea rests on the biological notion that ecological carrying capacity--or K--is the point where animals are most stressed, yet continuing to reproduce. Livestock in this case will be plentiful but unhealthy and if production is for beef, then problematic for producers. Vegetation will also be stressed at this point. If the producer harvests some of the herd, or maintains its size at a level that is economically feasible for his/her interests, then the "economic" carrying capacity will be reached. From a North American beef producer, this is a point at which the herd is small enough to allow for healthy, palatable forage for maximum weight-gain. In keeping with the ecological definition for carrying capacity, this point will generally fall somewhere within the range of K/2 or one half of the ultimate value of K. In keeping with economic logic of beef cattle production, that value will also correspond to the maximum utility for the cattle producer--the point at which harvesting animals yields a sustainable total production coupled with maximum financial gain for the producer.

This is also the point at which economic risk and environmental risk are roughly equal. For a cattle grower, particularly those producing calves, as is common practice in San Lázaro, optimum production naturally means fatter, healthier calves. Cattle buyers will purchase animals by weight and to some degree, with an eye to apparent health. By this logic, producing at or just under the economic carrying capacity for the semidesert grasslands is the goal from the perspective of "rational self-interest" as most neo-classical economists would posit. Go beyond that carrying capacity threshold by overstocking and the forage will degrade markedly, the calves and their mothers will loose weight, and the soil in the pasture will begin to exhibit signs of degradation (to be discussed in greater detail below). This is the point when increased economic risk will be coincident with increased environmental risk.

By extension, this theory will hold true for livestock production given a major shift in environmental conditions. For example, if the winter *equipatas* are insufficient to cause a flush of new growth in the grasslands, or if summer rains are to sparse to bring fall replacement from summer grazing, then the economic carrying capacity must move down the curve, towards lower stocking numbers of animals in a given pasture. To cope, the rancher must harvest the animals earlier than expected, provide extra forage, or move them to another, greener pasture. Hence, the second curve in Figure 3 signified by "Harvest of Animals" will also move to the right and towards greater numbers of animals until appropriate numbers have been reached on the grassland. The rancher must therefore walk the fine line between too many animals--to environmentally risky strategy, and too few animals--to economically risky-given that he could earn more with more animals. The curves in Figure 3 are flexible enough to illustrate changing environmental conditions, hence risk, but also demonstrate that economic concerns ultimately drive the risk or risk-averse behaviors of the rancher. The most important lesson from this model of carrying capacity is the strong relationship between environmental and economic goals as well as risks, particularly with regards to beef cattle or feeder calf production.

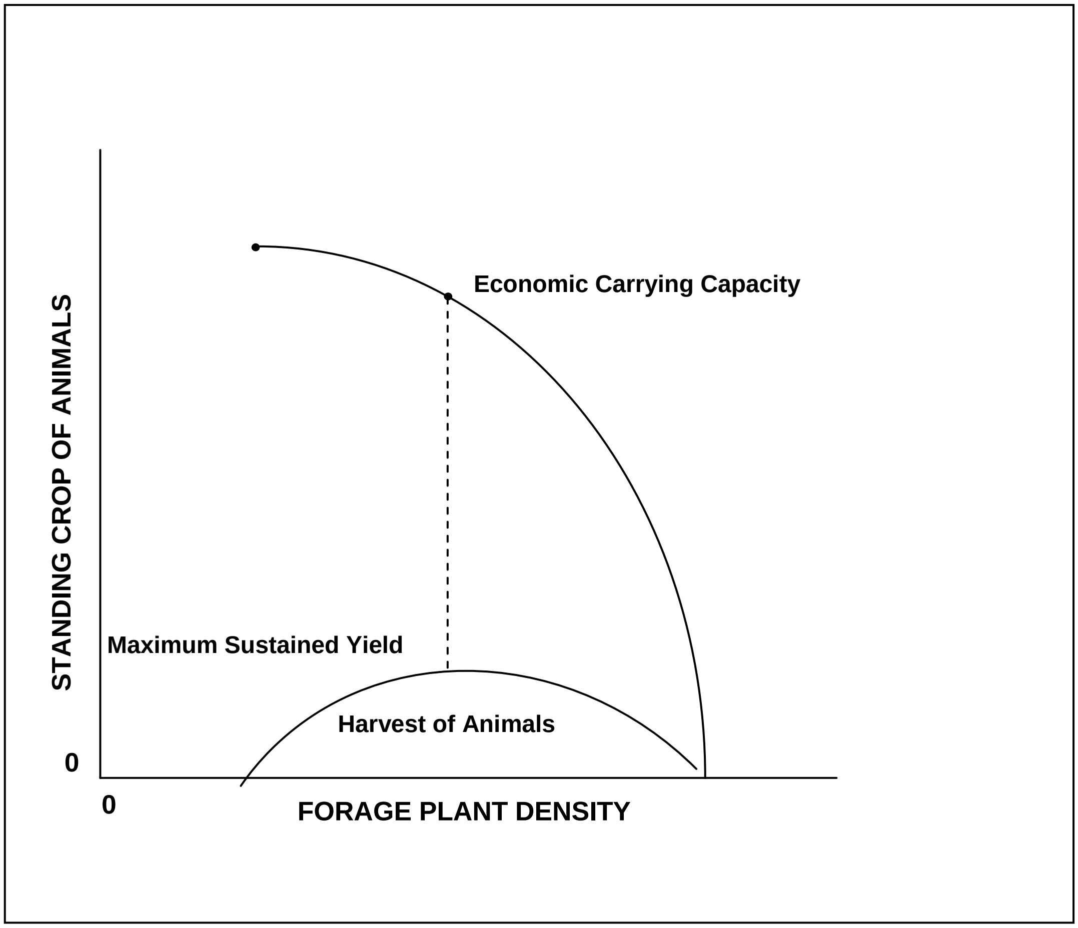


Figure 3.1. Carrying capacity relationships in a grazing system. Adapted from Caughley (1979) and Bell (1985).

Modeling Non-equilibrium Systems

Non-equilibrium theory takes the simplified model in Figure 3 and introduces successive layers of complexity that emphasize variability and non-homeostatic events. In a way, that complexity is more important than the predictable outcomes that a model should generate. Non-equilibrium assumes that predictability is virtually impossible. Rather, in a non-equilibrium model, trends are the only possible product of any attempt to model the interactions of herbivores and plant communities. For example, climate variation, precipitation, and temperature will inevitably change the amount, palatability, and nutritional value of the forage available for herbivores (the cattle). Management regimes, cattle behavior and to some degree-individual plant response to herbivory are the only relatively predictable outcomes of such a model. There are three main approaches to modeling non-equilibrium systems: a) the state and transition model; b) the threshold model; and c) the persistent non-equilibrium model.

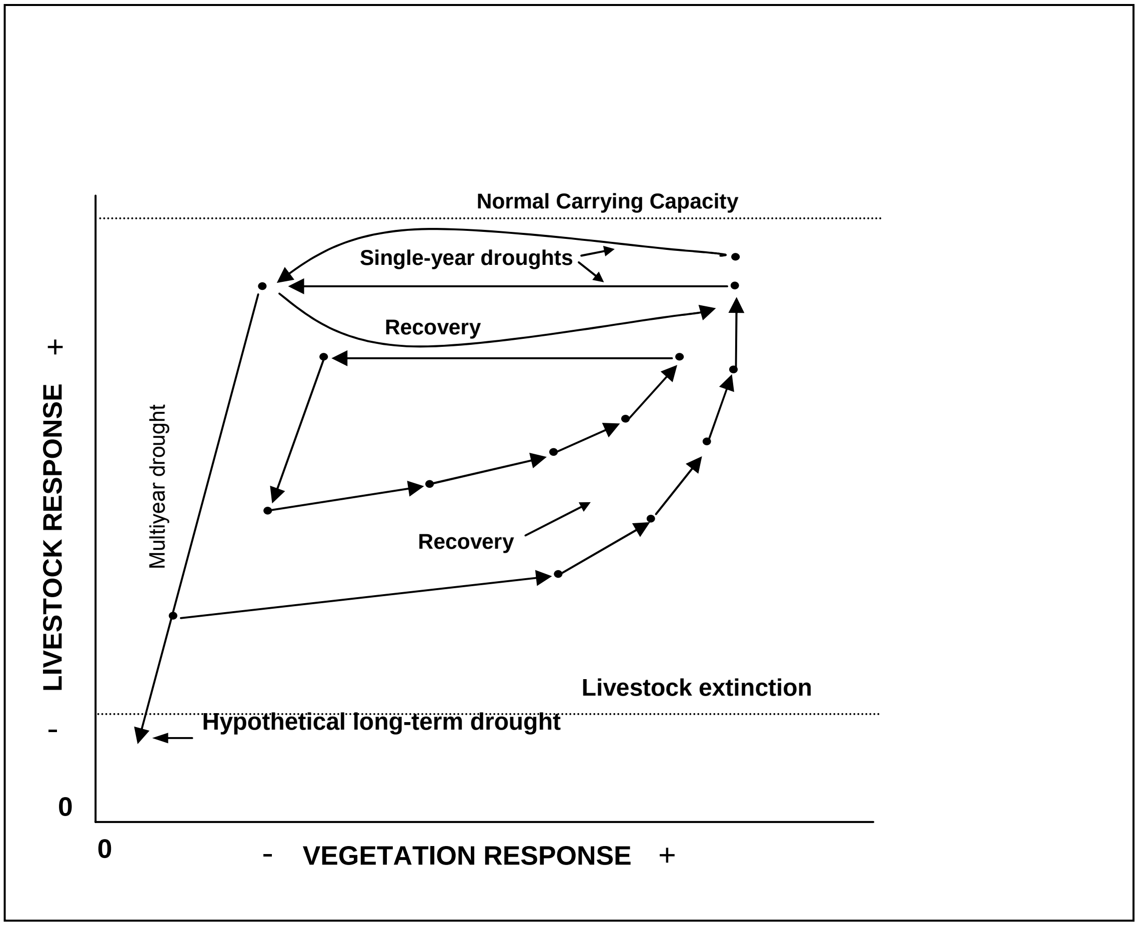


Figure 3.2. Vegetation and herbivore dynamics within a persistent non-equilibrium rangeland system. Adapted from Ellis et al. (1993).

Figure 4 represents an illustration of the states and transition model of non-equilibrium systems. The axis of Figure 3.2 is identical to that of Figure 3.1; however the inverse relationship between plant-animal populations (cattle and range plants) is more complicated and characterized by instability rather than regular climatic or stochastic events. The points that ascend on the far right of the figure represent increasing animal numbers due to steady rainfall conditions. Those on the left represent the animal population's response to drought conditions--a continuum between die-off without intervention or sell-off within closely managed systems. The lines in the upper-middle of the diagram show the impact of short-term drought events (stochastic environmental events) with short-term contraction and recovery. Responses to longer-term events are farther down the diagram. Towards the bottom of the diagram, we see the increasingly steep curve that needs to be ascended in order for the animals to recover from a multiyear drought indicated on the left. A series of points represent drought severity along the way that potentially limit each season's increase and may in fact, halt it permanently or temporarily.

Non-equilibrium systems present a challenge to monitoring range conditions with the ultimate goal of choosing from particular management scenarios. In the original Clements range model with even vegetative response to grazing and constant or predictable climate regimes, managers only had to be concerned with looking for species composition and plant communities that represented climax or subclimax states. A non-equilibrium system is characterized by extreme variability and therefore, a standard successional model does not apply. (Westoby, Walker et al. 1989) have successfully argued for a "state and transition model" to account for vegetation change and variability. In this model, vegetation is not compared along a single continuum of successional states. Plant communities in a particular area are instead described "by means of catalogues of alternative states and catalogues of possible transitions between states" (ibid. 266). A particular range may move from one state to another, or return to its original condition along a "transitional pathway," due to factors different from those that produced the initial change.

Another approach to describing non-equilibrium models of rangeland dynamics is the threshold model. A stable state is assumed to persist until the system is disturbed by some environmental factor (biotic, abiotic, or anthropogenic). The best analogy to describe this is as a ball coming to rest inside of a series of cups, the sides of which represent the thresholds that disturbance overcomes. Bringing the ball to rest in a new state of stability until such time as a disturbance returns it or advances it to a new or previous state. The thresholds are distinguished on the basis of changes in community physiognomy (plant growth form or life-history), and in soil properties that change overall site characteristics (Briske 2003). Because of this bias towards looking at physiognomy and soil characteristics, the primary application is to woody plant invasions of grasslands and savannas (Archer 1994). Thresholds are most apparent in these cases because the growth forms track climatic and soil-site changes, or the effects of previous events-especially fire-persist for longer periods than in herbaceous plants (Briske 2003: 604f). Because of the bias towards measuring woody plants, most range management strategies will not alter the vegetation significantly once the threshold has been crossed, hence making this explanation and methodology less useful from a range management perspective.

A final method for modeling non-equilibrium systems has been labeled the persistent non-equilibrium model (Briske et al. 2003: 606). This model assumes that arid are so constrained by variable climate effects-primarily precipitation-that plant-herbivore dynamics are relatively minor in impact. According to the persistent non-equilibrium model, persistent multi-year droughts contribute to herbivore death (or de-stocking) that prevents numbers from attaining carrying capacity in highly variable arid environments. Furthermore, the impact of grazing in these persistent non-equilibrium systems may be in fact, less important than in equilibrium systems where grazing intensity increases prior to mortality in a multi-year drought. It is also possible that the effect is magnified by the occurrence of highly productive zones in the landscape (such as riparian areas) that support high cattle numbers and delay mortality during the droughts (Illius and O'Connor 1999; Illius and O'Connor 2000). These highly productive zones are maintained in equilibrium while surrounding xeric environments in the landscape maintain the persistent non-equilibrium due to less intensive grazing. This latter alternative explanation is perhaps the best fit for the upper Santa Cruz River watershed and San Lázaro, because of the highly productive riparian areas surrounded by more xeric grasslands, mesquite bosques, and *encinals*.

Different combinations of factors affect the state of the vegetation and alter its ability to produce livestock to serve the purposes of the rancher. This makes monitoring and decision-making much more complicated in that the manager then must look at climate, vegetation type, successional stage, plant community type, and soil fertility-no small set of tasks even for expert ranchers. Ranching then becomes a matter of measuring probabilities and therefore risks. This is a formula for opportunitistic ranching-moving livestock around frequently and in response to the probability that range is better in one location rather than another. Conservative stocking numbers are usually calculated by looking at factors reminiscent of Clements' approach, especially forage density and subclimax plant communities. These indicators, however, are not well adapted to the real demands of the variable arid range environment. This is in fact a basic argument behind transhumant agropastoralism in landscapes like east Africa, Mongolia or the Navajo Nation in the United States (Scoones 1994; Fernandez and Allen-Diaz 1999). Agropastoralists in these environments are best served by being highly mobile, by keeping stock numbers at the maximum economic carrying capacity as determined by end-use, by maintaining loose tenure arrangements, and by learning to insightfully read the range conditions in ways that often elude sedentary agropastoralists.

The End of Equilibrium-Dominated Ecology

The conception of ecosystems as relatively stable structures within which organisms or populations 'seek' balance and domination is rooted within a deep foundational bias of western science that harkens back to classical thermodynamics and Cartesian-Newtonian conceptions of Nature that obeys laws. It is a nature that is predictable and hence controllable. This conception of a stable, controllable steady-state system is intimately linked with an economic system that seeks to control the environmental productivity of ecosystems for profit (Sullivan 1996: 3). From the 'equilibrium-centric' perspective, range managers have developed such important guiding principles (or at least, goals) to graze livestock on pastures within "sustained yield" and to understand an ecosystem's overall "carrying capacity" that will allow it to be exploited by a specific, predictable number of animals (and livestock producers). Conversely, it allows managers to assign limits and to judge "degradation". In this sense, the economic theory of "utility maximization" fits neatly with theoretical constructs of rangelands (or forests, fisheries and other exploitable natural ecosystems).

But as I have illustrated above, these concepts are deeply flawed from the beginning, particularly as they apply to arid lands where variability and chaotic abiotic conditions cannot be eliminated from the models. Ecosystems are not closed systems dealing with a largely passive abiotic environment. Rather, they are open, with fluid boundaries and sit within a very aggressive abiotic environment that can provide extremes unfamiliar to ecologists working in mesic climatic systems (where equilibrium-centered ideas of ecology were first developed). Arid systems are limited not by nutrients--as in mesic systems--so much as by the availability of water. In the semi-desert grasslands and oak savannahs of the Upper Santa Cruz Watershed, summertime rainfall is temporally and spatially variable--one location will receive inches of rainfall while another may receive none in a given precipitation event. Even during the winter when large Pacific frontal storms move through the area and deposit their precipitation over a large swath of territory that usually includes the entire watershed, the amount and regularity of these storms is unpredictable. A good winter might result in 5 or six soaking rainstorms spaced over a four-month period while another winter will yield just one storm. No matter what scale you look at, the area--like arid lands nearly everywhere--is subject to stochastic and chaotic water availability. This means that equilibrium-centered models of vegetation are inappropriate. It also means that predicating livestock producer behavior on this type of model is folly.

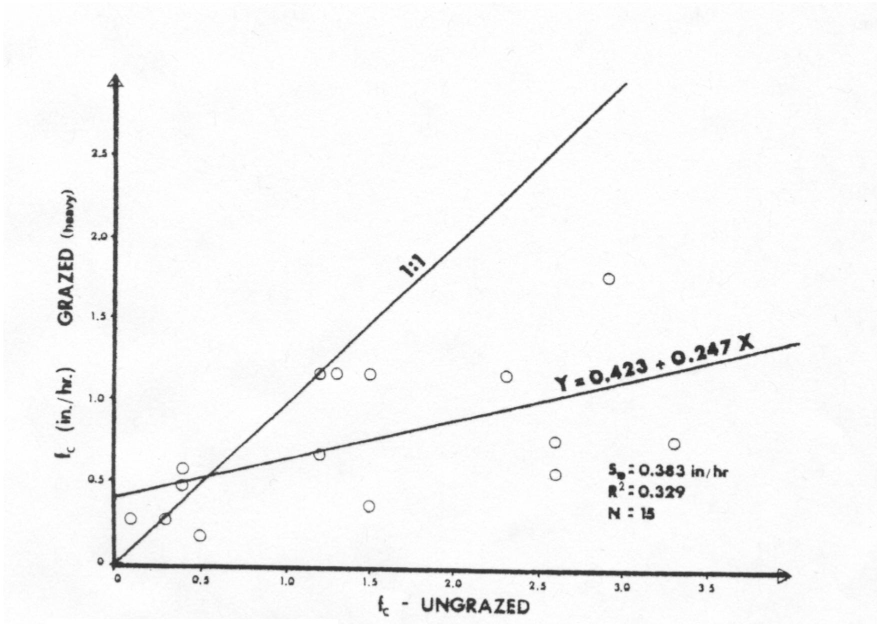
But equilibrium-centered thinking is not only rife in ecology, it has by secondary transmission, become an entrenched paradigm in the social science approaches that depend upon ecological thinking. Hence, it is critical that I dissect the most important ecological models that underlie these studies. In so doing, I will attempt to disentangle mesic system approaches to ecology and human behavior as well as illustrate a more appropriate means to understanding human-environment interactions in arid areas where abiotic factors such as the availability of water make stability and "sustainability" difficult, moving targets. It means that much thinking about societies being "in-balance" with their natural environment--at least in arid systems--falls prey to the same fallacious thinking that has since been rejected by many in the field of ecology since the early 1990s. In the words of environmental historian Richard White (2001): "Nature as an easy reference point and as a constant standard to measure human actions became deeply problematic." Scholars in the ecologically oriented social sciences must realize this to be successful.

Thinking like a Watershed: Synthesizing New Ecology with Watershed Science

The preceding arguments might lead reader to conclude that arid systems are resilient, to environmentally noisy, and too variable to show measurable signs of "degradation" or to ask real questions about their ability to support a given livestock management strategy. This is not to say that "degradation" cannot or does not occur in arid systems and that livestock producers won't engage in risky, environmentally detrimental behaviors. In fact, it might be argued that attempts by policy makers to re-establish equilibrium into a non-equilibrium system are at the very heart of this result. This is particularly true where states seek to make permanent or restrict the movement of transhumant agropastoralists (Fernandez and Allen-Diaz 1999).

Furthermore, there is good reason to judge not just the condition of the ranges in San Lázaro and elsewhere in the region, but also the conditions of the watershed itself as "degraded" or at the very least, in a transition that might result in non-reversible changes to important landscape attributes. The key issues here revolve around the maintenance of soil structure, soil fertility and consequent infiltration-all key underpinnings for watershed health. While vegetation-livestock dynamics play a pivotal role in this, the adoption of non-equilibrium, persistent non-equilibrium or "states and transitions" models for describing rangeland health does not address some of these other equally critical issues. In particular, any assessment of rangeland must include health of the larger landscape-the watershed. As we examine watershed-scale health and attempt to disentangle anthropogenic changes with in it, infiltration, surface runoff, or changes in soil structure that impede infiltration and percolation become important or potentially more important than simple plant-herbivore interactions. We must, therefore, seek to insert these measures into our theoretical model if we want to accurately assess watershed health, and if we want to assign real prescriptions for improving the situation.

Researchers, watershed managers, and others have acknowledged that in southwestern arid watersheds, infiltration is of primary concern (Gifford and Hawkins 1978; Bahre 1991) for watershed health. Several physical characteristics influence infiltration in these systems, in particular, soil texture, soil organic material, soil aggregation, and overall soil structure. The sum results of these characteristics are found in pore size, with larger pore sizes leading to generally higher infiltration rates. Anthropogenic or management impacts on these systems include increasing compaction, reduction of organic material through biomass removal, and alterations of soil structure. Biological activity is also an important influence on infiltration rates. Fungi, bacteria, plant roots, worms, insects, macroinvertebrates all influence pore size, and soil aggregation. Humans alter this system through the reduction of organic material--the food source at the heart of these ecological systems, reduce plant cover, or change conditions by altering the plant species that provide overstory to the biotic soil system. Lastly, ground cover influences infiltration by providing a rougher or smoother surface for overland flow. The rougher the surface, the greater the standing time water will have in place and the lower the soil erosion.



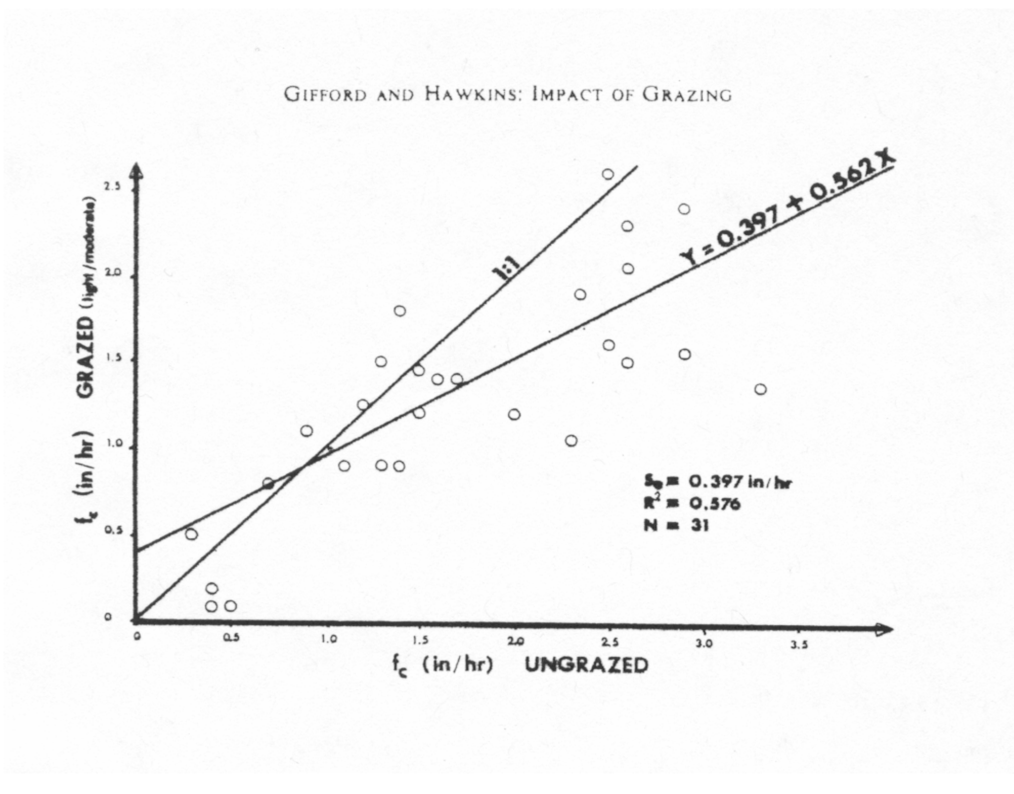


Figure 3.3. The relationship between grazing intensity and infiltration rates (Gifford and Hawkins 1978).

Cattle, as well as other large herbivores, can have large-scale impacts on soil structure, fertility and infiltration in watersheds. In fact, as Trimble and Mendel (1995) note in the title of their thorough review of the subject--the cow is a geomorphic agent. The herds of animals, through biomechanical effects and grazing patterns directly impact fluvial geomorphology and adversely impact watershed conditions from a hydrological perspective. More specifically, cattle shear off the edges of stream banks, leave trails, terraces and ingress zones wherever topography presents an obstacle to the 900-pound beasts. The impact of their hooves has a tendency to reduce soil infiltration rates (Gifford and Hawkins 1978) through a number of different mechanisms, the most fundamental involve compaction, loss of A-horizon soil structure, and removal of biomass that protect soils from precipitation impact (Trimble and Mendel 1995) as well as alteration or removal of plant cover (Archer and Smeins 1991).

Livestock impacts may to be found throughout northwestern Mexican watersheds such as the upper Santa Cruz, although their seriousness may be distributed differently depending upon the hydrologic or geologic conditions. In this case study, I will divide them between two areas-riparian and upland. As I have described earlier in this chapter, vegetation varies widely throughout the watershed including a micro-landscape scale of a hectare or less, in all plant communities and life-zones. Although we would expect this variation to lead to a diversity of impacts, the most important physical factors: gradient, roughness, vegetative cover, and soil characteristics are most starkly different between these upland and bottomland system. The level of grazing intensity appears to generate the largest variation in impacts as seen in Figure 5 above. Bottomland areas, because of their high productivity and highly palatable forage are often utilized to a greater extent than neighboring uplands (in keeping with the persistent non-equilibrium model as well) (Briggs 1996). Bottomland or riparian ecosystems are more attractive to cattle in cases such as San Lázaro, because of increased available forage, fewer impediments to travel, lack of regular herding or management, and the availability of water.

Riparian impacts are difficult to adequately quantify, so I must rely upon a more qualitative description of vegetation characteristics. This is largely because vegetation studies in this portion of the watershed (or much of it for that matter) are almost non-existent (Solis and Briggs 1998; Solis and Briggs 2001). The most important impacts of livestock grazing in riparian areas derive from the combination of removal of the most palatable plant species (*Salix spp.* and *Carex spp.* for example) as well as morphological changes to stream channels due to cattle trails, premature bank sloughing, and higher-than-expected sediment loads. Higher sediment loads will also impact species composition, favoring more strand species and suppressing some tree species that favor highly scoured beds. As streams attempt to reestablish more even sediment to water ratios, channels may widen considerably and base flows may diminish. As a result of morphological, hydrological and herbivory vectors there may be a wholesale change in riparian vegetation.

Upland ecosystems, however, are still important for livestock grazing, especially where *ejidatarios* do not have access to bottomlands due to the placement of their pastures. Furthermore, even though utilization of these areas may be lessened by the proximity of rich, riparian resources, cattle grazing may still generate significant impacts due to the steepness, thinner soils, and less resilient vegetation characteristics. Slopes on at least 44 percent of the ejido are at 15 percent gradient or greater (Gray, Briggs and Murrieta 1998). Soils have not been adequately sampled nor are soil surveys available, though similar areas downstream in the U.S. portion of the watershed illustrate the tendency for soils in upland areas to be characteristically thinner than bottomlands with thick alluvial deposits (Halpenny and Halpenny 1988). Lastly grasslands are characteristically less resilient than bottomland ecosystems that are adapted to high rates of flux.

Environmental History and Change

The San Lázaro case study also demands that we situate the research within the area's long historical background of environmental change. Worster (1984:1) lamented that natural history was often treated as ahistorical by both those studying natural systems and those studying human history. Since these proclamations in the early 1980s, much has changed with the birth and rapid florescence of environmental history (e.g. Worster 1985, 1990; Cronon 1983, 1990; White 2001). Others working the realm of historical ecology (Crumley 1994) have asked deeper questions of longer time-scale data that speak to the persistence of societies in the face of long-term environmental change. These approaches have in common the emphasis that nature is not a passive actor to be humanized, but acts as both physical agent and conduit of change through which humans must adapt or fail. My research in the Upper Santa Cruz Watershed draws upon this intellectual line by offering that ecological conditions representing a single snapshot of time cannot be divorced of their context in a changing landscape. At the same time, human behavior in the environment must also be contextualized within a history of practice that has developed *in situ* or imported into the environment (Nazarea 1999; Nyerges 1997).

Traditional Human-Ecological Approaches to Tenure

The previous material should leave no doubt about the difficulties presented by physical environment in which the *ejidatarios* of San Lázaro find themselves. On the one hand, they are potential stewards of a rich--though inconsistent--ecosystem with abundant resources for sustaining human life. On the other hand, *ejidatarios* are faced with extreme climate variability and not far away, socially constructed vulnerabilities to these conditions. According to traditional cultural ecology logic and use and land tenure might reflect the vagaries of these conditions-at least under ideal conditions (Boserup 1965; Bentley 1987; Netting 1993). Ranchers would use common lands for the least productive, least intensive activities-extensive grazing-while the most fertile lands on the floodplain are used for intensive farming and specialized pasture for more economically remunerative activities (Sheridan 1988). Land tenure in San Lázaro however, does not follow this logic--it instead has become even more flexible and possibly mal-adaptive. This is largely due to historic policy and economic signals from outside of the community that I will outline in subsequent chapters.

While there should be little doubt to long-time observers of Mexico and the developing world that inconsistent and uneven development policies have heavily influenced how locals respond to macroeconomic factors and local constraints, chaotic environmental signals are also part of the problem. These environmental signals originate in a distinctly non-equilibrium system, where climate variability combined with localized soil conditions, inconsistent livestock forage, and wildly variable surface water availability all combine to make a steady, predictable outcome for livestock producers impossible. Furthermore, these signals usually contradict the directives of agricultural ministries, credit-lending institutions and others involved in guiding local agricultural development and land use decisions.

The rancher-farmers of San Lázaro are active in the production of their immediate place--the watershed conditions, the landscape, the water extraction technologies, the local adaptations to shifting political economy, and the patterns of human land use. The production of "place" has been described of late as one of a few primary unifying themes in contemporary political ecology (Paulson and Gezon 2005: 2) as practitioners and students of the field seek to move beyond wildly divergent approaches (Robbins 2004: 52). These local cattlemen, like urbanites in large cities, fishermen in coastal communities, or agribusiness farmers participate in activities that perpetuate their place, whether that place is defined as an ecological "footprint", as a cultural or working landscape, or as a watershed. I have sought to describe this space in terms of watershed conditions--many of which take on a somewhat ahistorical nature, especially when divorced from the humans within. To rectify this situation, it is vital for me to introduce a critical framework from which to view place-producing activities that constitute a real political ecology. That critical framework can be boiled down to one of the earliest themes in cultural and political ecology as well as a guiding agenda item for modernist developers of many stripes: tenure. Tenure (often writ large as territorialization) defines the pace and means of access for local ranchers to their pastures, to irrigation water for forage production, to entry and exit from the ejido system itself (Greenberg 1998; Sheridan 1988; Wolf 1972). It is the local manifestation of economic policy and the local lens for focusing economic relationships. It is, in sum, the base of economic power that is somehow distributed by market, state, community, or other means. The distribution of tenure generates the landed and landless, as well as conflict and over-exploitation.

Also implicit in tenure relationships are some important assumptions about ecological relationships. This is especially true for the fundamental relationship between biotic factors and ecological productivity, whether agricultural or otherwise. Ideally, the assignment of specific tenure arrangements by markets, state regulation or local political economy informs how much land, forage, water, or herbivores can be brought together by a rancher or group of ranchers to *produce* a commodity--in this case beef, calves, or milk products while at the same time maintaining essential--though elusive--range conditions. Tenure allows for access by the proprietor but also comes with ecological or social responsibilities that may or may not be enforced and/or adhered to by those possessing it. This makes tenure the essential interface between policy and the local ecosystem (or place). But tenure is heavily influenced by assumptions of what are appropriate ecological conditions--including homeostasis--however elusive. Therefore, in this section I will focus attention some prominent social science treatments of tenure and the intellectual disjunction that is created by theories of tenure that rely upon equilibrium-based models of ecology. Unfortunately, these models continue to inform much scholarship and practice around tenure.

Tenure has been the subject of scholarship since the time of Morgan (1877), became a fulcrum of development in the colonial and post-colonial worlds (Escobar 1995), and attained real importance for cultural ecologists, students of peasant studies, and political ecologists since. Both agricultural development institutions and scholars focused upon smallholder livelihoods (most notably cultural ecologists and their academic kin). Yet have missed these chaotic relationships that dominate arid ecosystems because tenure is quite often assigned on the basis of what is productive and sustainable in mesic ecosystems. One excellent example of the extreme danger inherent in ascribing the wrong idea to these dry land ecosystems was the application of the Homestead Act allocating 160 acres of variable climate shortgrass prairie to farmers in the Southwestern and Midwestern United States in the late 1800s only to see it expel soil and refugees during the Dust Bowl of the early 20th century. Furthermore, variability in the biotic and abiotic environments are usually ignored by governments re-engineering tenure arrangements (Scott 1998: 263f). In many cases, both the scholars and would-be development managers draw from the same wells of thought about sustainability and equilibria. These primary approaches include neoclassical, cultural ecological intensive-extensive models (namely that promoted by Netting and Boserup), Chayanovian, Marxian, and common-pool resource analysis. These intellectual treatments have been applied differently depending upon the desired outcome--whether it is an increase in agricultural productivity for developers or a logical explanation of agricultural practice for students of small-scale agriculture.

Many of these approaches predict, with limited success, the tenure relationships that should arise in communities such as San Lázaro. Land tenure relates to agricultural production by defining the access to the means of production and by setting out the rights, duties, and obligations related to using those means. This bundle of rights can be established internally-within the community, and externally-by states, or in a mixture of both. The most significant relationships between land tenure institutions and agricultural production are to be found in the ways that land tenure arrangements will generally match and determine land use practices (Netting 1993: 158).

Tenure should also mirror the ecological relationships between smallholders and their landscape. If land and water are scarce for farming, then farmers should hold lands and concomitant water rights privately in order to maximize their access to these limited resources. On the other hand, if ranching is hard to accomplish on few hectares of land, then ranchers would do all they can to use large tracks of land in common--since ownership of sufficient tracts is beyond their economic reach and ability to control access of their neighbors (Sheridan 1988).

The case study at hand is one that also focuses upon the relationship between tenure, risk, and irrigation, since in most of the world water, not land, is the limiting resource for production and survival (Johnston and Donahue 1998: 2). In the case of San Lázaro, the bundle of rights and responsibilities associated with land tenure help to define how resources related to livelihood--water--are accessed.

The most primary among these intellectual sources--the neoclassical theory of utility maximization--assumes that land and water resources, though finite, are consistent across the landscape. Costs for production will go up as these finite resources become more limited and so the rational, profit maximizing producer will find ways to economize their use through intensive production or will seek to secure more of the limited inputs in a situation where extensive production is possible. Furthermore, throughout a lifetime of agricultural production, these natural resources will yield roughly similar results if a given agricultural producer places sufficient inputs, capital, and labor into the agricultural system. This neoclassical logic nearly buries the actual natural environment from within the standard utility maximization model. Land and its fruits (like fresh water or fertile soil) are considered to be just another input. For the larger part of the last 50 years of neoclassical ascendancy in agricultural development thought, the vagaries of that input were simply not considered relevant (especially when combined with pervasive agricultural engineering feats preferred by proponents). Often the engineering-based solutions were themselves the means of stepping around the apparent "maldistribution" of resources such as irrigation water secured by constructing large dams or substituting inorganic fertilizers for declining soil fertility.

More recently some scholars in the neoclassical intellectual camp have sought to partition "natural" capital from other forms of capital, arguing that neither category is substitutable for the other, therefore yielding--in theory--a better stewardship of the former. One result of this scholarship materializes in the promotion of so-called "market-based solutions" to persistent environmental problems in many arenas including small-scale agriculture does bespeak an acknowledgement of the fact that natural landscapes cannot be counted upon to deliver consistent and equitable distribution of natural resources to all. Yet, a market-based solution based on the compartmentalization of "natural" from other forms of capital still ignores the chaotic reality in which arid-land producers find themselves embedded. Furthermore, this approach also ignores the lack of access to other forms of capital, credit, and inputs that make farming or ranching feasible for a small-scale producer such as those in San Lázaro. In fact for this lack of available credit and other resources, combined with extreme environmental variability is really the blow that has reduced ranching-farming in the region to a largely hapless exercise.

The neoclassical supposition that privatization of tenure arrangements, driven by the belief that markets will naturally adjust to allow maximum efficiency, is a guiding ideology that the Mexican government has employed in adopting land privatization schemes. This ideology and its impacts make up the "political" side of the equation in the recent political ecology of San Lázaro. The fact that application of this ideology to arid systems like San Lázaro yields such painful results locally is part of the evidence that it does not adequately compensate for the environmental variability inherent in arid land agropastoralism. This political variable and its very material results will be discussed at length in subsequent chapters.

Cultural Ecological Approaches to Tenure and the Environment

Researchers working on tenure from the social sciences--primarily utilizing cultural ecology and its direct predecessor, political ecology have also sought to sort out the often tangled relationships between ownership and ecological conditions, very often as critiques of the neoclassical approach outlined above. While neoclassical approaches tend to simplify the relationship between tenure, environment and agricultural practice, cultural and political ecological treatments very often reveal for more complexity. However, cultural ecology too drew from the same well of thought as traditional, equilibrium-centered ecology (Kottak 1999:24). Researchers working in environments as varied as the Philippines (Conklin 1954), Fiji (Sahlins 1957), the Amazon basin (Wagley 1956), the Kalahari Desert (Lee 1969); and New Guinea (Rappaport 1967) utilized a homeostatic model of ecosystems in which humans might be subjected to similar regimens of balance (Scoones 1999: 484).

As a direct descendent of cultural ecology, a not insignificant number of early political ecologists have also succumbed to this intellectual trap (cf. Hecht and Cockburn 1990; Moran 1981; Stonich 1993). Unlike their intellectual cousins in cultural ecology, these early political ecologists spent a great deal more time on understanding the macro and micro-level implications of market integration and dislocation of traditional resource management, which overshadows concern with pre-intervention equilibrium conditions that fascinated previous approaches (Peet and Watts 1996: 5). Environmental variability, while important to some early analyses (e.g. Blaikie and Brookfield 1987; Bryant 1992), still very often continues to languish outside of the new explanatory roles for scientific knowledge, power or political critique (Zimmerer 1996: 162).

Within political ecology and ecological anthropology, a determined group of scholars acknowledge the chaotic nature of many different environments (not just arid ones) (e.g. Lansing and Kremmer 1993; Park 1992, 1993; Scoones 1995, 1997). Scholars working in history and archaeology too have acknowledged the importance of environmental variation to cultural behavior (Pollard 1982; Spalding 1984). Despite these adherents to a complex ecological worldview, the persistent ramifications of this bias are present in the applied ecologically oriented social sciences and yield inaccurate analyses of arid-land case studies such as San Lázaro, in much the same way that equilibrium-centered analyses cannot properly address the case study's variable arid ecosystem dynamics.

Cultural ecologists have concerned themselves with the connections between human groups--usually small-scaled for both methodological and sometimes ideological reasons--and their environment as mediated by cultural practice. The broad outlines of cultural ecology were stated neatly by Steward (1955: 243) as the study of "the adaptive process by which the nature of society and an unpredictable number of features of culture are affected by the basic adjustment which man utilizes a given environment." Steward's thesis begins with the revision of the old "cultural core" and expanding the functionalism of the early 20th century field to fit a broad, ecological subsistence context that could be quantified by his students (Mintz and Wolf primarily) as well as others (e.g., Rappaport 1968; Vayda 1969). Hidden within the field was a materialism that trained the anthropologist's eyes upon environmental and livelihood-related variables.

This materialism was no where else more apparent than in Rappaport's *Pigs for the Ancestors* (1968), which set out a bold new ecology based on energetic flows through an anthropocentric ecosystem. Rappaport's thesis was built on the notion that a bounded analytical model could be created that allowed the researcher to isolate the energetic flows through the ecosystem. These flows, he would argue, created incentives for specific cognitive constructs that then fed into ideological behaviors that preserved the adaptiveness of human behaviors (1979: 98). Yet Rappaport's early model retains an important dialectic between the ecosystem and its human inhabitants that relies exclusively upon the Odum's idea that ecosystems sought energetic homeostasis above all else. If variability is acknowledged within this view, it is only as temporary perturbations that ecosystem actors then return to normalcy by adjusting behaviors (such as warfare, ritual sacrifice, and population control).

Another example, Robert Netting focused much of his life's work on understanding the dynamics of intensive-extensive smallholder agriculture. While Netting focused more upon smallholder farmers as distinguished from agropastoralists (1993: 3), his insights draw into focus some common ecological relationships. Most importantly, Netting pointed out that agriculturalists will chose to intensify agricultural practice in areas where tenure is private and resources concentrated, while practicing more extensive agriculture in areas where resources are more diffuse and control is less likely due to environmental variability (ibid.: *passim*). Netting argued that this yields better results for farm households while lowering external inputs that might result in less efficiency and more detrimental environmental impacts. On the other hand, attempts by states or other outside institutions to change these tenure relationships and/or to introduce Green Revolution technologies would yield degradation (for both smallholders and their environment). While the extensive-intensive continuum is a vital piece of the puzzle in terms of San Lázaro, it assumes that any practice within this complex is predicated upon a thorough local knowledge of predictable environmental conditions and that homeostasis is the ultimate goal of the human and non-human communities involved (Netting 1981: i, 130). For example, Netting (ibid. 225) explains in *Balancing on an Alp* that:

> *"The local ecosystem seemed to strike a complex balance with its alpine environment and means of production, sustaining life without the threat of want, but with few luxuries, while protecting and carefully harvesting renewable resources. This equilibrium was not the result of natural forces, as the wilderness of the American Rockies might be. Rather, it was created and maintained by intensive human effort for the physical benefits it could confer".*

This clearly not applicable to the case study of San Lázaro as the contemporary community has only existed for two or three generations and environmental homeostasis is foolish to imply in such a variable climate detailed above.

Cultural ecologists came of age in the era of Eugene Odum and the equilibrium-centric model of ecosystems prevailed. Even with its limits carefully defined by the author himself, Netting's model of ecological balance in the Swiss community of Törbel has been absorbed into the preferred explanations of culture ecologists since. This equilibrium-centric vision of human-environment relations can be found in other influential works of the past half-century including Rappaport (1968), Steward (1955), and Vayda (1969). In many cases, the models of cultural ecological systems relied explicitly on successional stages (Rappaport 1971: 131) or on an implied balance the perturbations of create negative feedbacks resulting a number of human social consequences that then restore equilibrium (Vayda 1969: 204). Through this lens, culture is see as an "adaptation" that maintains critical environmental conditions and energy flows. Primary among those "cultural adaptations" is the notion of tenure, whether extensive or intensive.

Cultural ecologists beginning with Julian Steward (1955) and continuing to Rappaport (1979) and Netting (1993) have relied upon the small-scale studies in "indigenous" or smallholder settings, with little articulation to the wider political economic universe that might impinge upon these communities. While most of the researchers during this period actively eschewed the Redfieldian dichotomy between the "little community" and the rest of the world (Redfield 1955), they persistently replicated an ethnographic methodology focused upon the smallest of community scales for a number of reasons, not the least of which being that for studies of local ecology to work, they needed to be as nearly autotrophic as possible (capturing local energy flows and maintaining a relatively closed system) (cf. Rappaport 1968). The limit of this method was to ignore many of the external or larger-scale variables that might impinge upon local phenomena and to thereby assume an analytically bounded--but ultimately balanced--system. While this strategy is useful for students of human ecology, it develops a false sense of environmental closure (Orlove 1980) and fails to capture the vicissitudes of the wider world as well as relying heavily on the dubious construct of "carrying capacity" (Behnke and Scoones 1993). Later, cultural ecologists such as Rappaport (1999) and even Steward himself (1977: 56) struggled to include the influences that global capitalism, state interference, ideology, migration, and pollution might all have on these "closed" human ecosystems. For this reason among others, political ecology arose in the 1980s and 1990s to better address these connections (Robbins 2004: 36).

Common-pool Resources: The Tragedy of the Commons

Common-property studies have provided a fruitful body of literature that examines property rights and, in particular, the sustainable management of natural resources by groups or collectives of resource users. One of the most significant contributions of these studies was the clarification of property rights and definition of property regimes (Bromley et al. 1992). Four rights can be applied to property: the right to access and use a resource; the right to make decisions for a resource individually or through an institution (manage); the right to exclude others from using the resource; and the right to sell or lease the preceding rights (Schlager and Ostrom 1993). Property regimes are defined by who holds these rights. Natural resources, put simply, can be held by state, private, or common-property regimes and any combination of the three depending upon how the rights are distributed or exist in a condition of open access (Berkes 1989).

Common-property studies originated as a critique of Garrett Hardin's "Tragedy of the Commons" theory (1968). Hardin's theory states that actor’s unrestricted access (a lack of enforceable tenure arrangements in other words) will yield over-exploitation of the resource in question (land, soil, fish, forests, rangeland, etc.). Many social scientists and human ecologists have countered that this theory only holds where access is not clearly governed and that a plethora of institutions awaits the careful scholarly analysis of a successful common pool resource (CPR) system (e.g., McCay and Acheson 1987; Ostrom 1990; Tang 1992). Arid land and agropastoral ecosystems are no exception (e.g., Baker 1997; Berkes 1989; Monbiot 1994). CPR control regimes dominate where private control of these resources where environmental risk is too difficult to sustain on an individual level (Park 1993; Sheridan 1988). Furthermore, under ideal conditions CPR regimes are critical institutional adaptations where the spatial or temporal variability of the resource makes individual control impossible. While the possibility for environmental degradation are high under these conditions, problems of decline in the common resource are not entirely explainable as tragic outcomes of failed collective management, where the environment is seen as somehow passive. Rather, as is the case in arid systems, environmental variability may also lead to failure--not the necessarily because of faulty human resource control regimes (which often become a convenient scapegoat for state-driven interventions) (Sullivan 1996: 1). Thus, while the case of degradation in a collectively managed ejido or a shared river in northwestern Mexico might appear to neatly fit the scenario of the "commons dilemma" in the classic sense, a more complex story can be told when the true chaotic nature of the environment is included from the onset.

Common property studies (like this one) must therefore embrace the new acknowledgement of the important role for extreme variability in ecological systems. This research project will draw from the study of CPR regimes--especially given that the formally codified tenure relationships of the ejido are prefaced on the idea that rangelands, water resources and even farmland are held in common for the benefit of the community--at least in theory. Of course, this was rarely the case in actual practice, owing to a host of social, political, and economic factors that I will describe in Chapters Five and Six. That these variables forced the failure of CPR regimes and their replacement with private property regimes should be an obvious conclusion. However, the region's extreme climate variability, combined with the spatial variability of the watershed's soils, water sources and most importantly, livestock forage makes a powerful variable that constantly dogged the *ejidatarios*' struggles to wrest economic benefit from their landscape and undercut efforts to either collectively or individually manage their resources in an effective manner. Therefore, unlike the traditional ethnographic approach to the study of CPR regimes, this dissertation will ask the reader to reframe questions about causation in terms of ecological change as much as typical sociocultural relationships.

Political Ecological Approaches

If cultural ecologists persisted in recreating a story of closed, balanced anthropocentric ecosystems based on timeless agricultural conservatism, their intellectual offspring, political ecologists framed a completely different story based on ecological imbalance due to outside interference which resulted in the decay of conservative rural economies. Beginning with Nietschmann's (1973) impressive work on the monetization and eventual breakdown of the sea turtle trade along the Miskito Coast of Nicaragua, early scholarship in the political ecology extensively explored the "ecology of degradation" rather than that of "sustainability" as portrayed by students of cultural ecology. While the proponents of the later sought to define, quantify and understand enthalpy in anthropocentric ecosystems, the former instead began to build an understanding of the more entropic side of the equation. While no one would doubt that either side's insights are useful, scholars since (Biersack 1999: 12) have argued that only the combination of both methodological lenses can create a realistic understanding of human-environment interactions. But moreover, political ecology is the rejection of "culture as island" approach or the words of Bates and Lees, "while historical change and external influences might once have been regarded as annoying distractions or distortions of indigenous systems, they are now the focus of attention" (1996: 2).

Political ecologists themselves (e.g., Greenberg and Park 1994; Robbins 2004) have argued that the field has become a lose rubric, containing many separate discourses, methods, and theoretical foci. Political ecologists, beginning with Eric Wolf's path-breaking definition in his work "Ownership and Political Ecology" (1972) set out access as a prime area of inquiry for the field that has since influenced its early and current works (cf. Blaikie and Brookfield 1987; Bryant 1992). However, access is not the sole focus of political ecologists today as (cf., Greenberg and Park 1994; Peet and Watts 1996). Political ecologists housed within anthropology, geography, sociology, and political science have also incorporated additional studies environmental history (e.g. Cronon 1992; Crosby 1994; Worster 1993), poststructuralist discourse theory (e.g. Escobar 1999), neo-Marxian analysis (e.g. Collins 1992; Leff 1995; O'Connor 1998), among other areas into their research design and analysis. Since, however, this study is largely restricted both theoretically and methodologically to concerns of tenure and resource access, I will focus on those relationships within the subfield.

The Political Ecology of Unsustainable Practice

Political ecologists have constructed several important discourses in their subdiscipline. According to Robbins (2004), political ecologists have created four dominant narratives around (1) degradation and marginalization; (2) environmental conflict; (3) conservation and control; and (4) environmental identity and social movements. Gezon and Paulson (2005: 1) assert that political ecologists have pursued intellectual paths that relate local community to larger context as an explanation for resource use patterns. A common thread within these seemingly disparate approaches is the politization of nature. According to this thesis human actions are resulting in the modification of nature--its humanization in the Hegelian sense--that follow patterns explicitly traceable back to policy decisions. These policy decisions occur at the micro-level (the household or individual resource user), at the meso-level (the organization, the community, or the regional levels), or at the macro-level (the state, the global trade organization, the multinational corporation, the planet). For at least the macro and meso-levels, a type of passivity is implied in natural system. Nature is the stage upon which these narratives are articulated and humanized nature is the result of patterns of policy-driven use. At the local level at least, environmental change—usually characterized as degradation—is placed in the context of generating or influencing marginality. In many of these macro and meso-level narratives (e.g., Bryant 1998; Durrenberger 1997; Escobar 1996; Hecht and Cockburn 1990; Schmink and Woods 1987; Stonich and Bailey 2000; Weaver 1996) the privileged agents of the system are political not environmental actors (cf., Emanuel and Greenberg 2000; Greenberg 1998; McGuire 1997; Park 1992, 1993; Romero et al. 1999).

Much of this passive-nature perspective originates with earlier Marxian notions of the environment. Building on the Marxian notion that capital accumulation is a product of the exploitation of surplus labor and of nature (then humanized in the broadest sense), political ecologists of the 1980s and early 1990s concerned themselves with one of major the end products thereof--degradation (O'Connor 1998). For these materialists, environmental degradation is inevitable where capitalism (or other extra-local economic signals including socialist, feudalist, or authoritarian) inserts itself into formerly innocuous local production (e.g., Blaikie and Brookfield 1987: 23f; Hornborg 2001: 13; Moran 1981: 223; Popermayer 1984: 421). This perspective is particularly pertinent to the degradation and marginalization thesis that Robbins defined (2004: 14). Implicit in this model is that the dominant agents are locals (those creating the degradation), while the wider economic forces of capital accumulation are indirect but ultimately responsible agents of environmental change.

Unfortunately, the initial condition in this meta-narrative political ecology of unsustainable practice frequently relies upon the equilibrium-centered ecology. From this premise comes the other major assumption of this political ecology model: that local practice is somehow "sustainable" prior to interventions by global capitalism and post-intervention are "unsustainable". As discussed earlier in this chapter, neither précis: sustainability or lack thereof is appropriate in the case of arid systems where the fundamental precondition for the former--ecosystem stability--is simply not present. With extreme variability the norm, we cannot accurately present the vegetative communities in a rangeland ecosystem for example, as being stable and also cannot assign an appropriate carrying capacity that defines the upper limits of use. There is therefore no deminimus condition.

Hence, while the marginalization and degradation thesis of political ecology is certainly not lost its usefulness, this particular explanation must be based on a more robust study of the conditions prior to and post-intervention—especially in arid systems or under highly heterogeneous environments. Recent work in panarchy suggests that political ecologists utilizing the argument look carefully at assumptions about local system resilience and hysteresis (Gunderson and Holling 2002). In many cases, degradation is cumulative and progressive, leading to transitions into new states for the ecosystems under study. In arid systems, because the climate yields years of drought and then sudden abundance, degradation itself is difficult to define (Scoones 1994: 30; Westoby et al. 1989).

What may be a more appropriate approach to the argument is to discuss degradation from the "emic" perspective of local human users. Once the forest, fishery or pasture has converted into something that has lost utility for producers, we might then assign it a new state. The new state is assigned (or more likely contested) by particular groups as a reflection of that utility. For example, as cattle production becomes less remunerative in the face of rangeland conditions, ranchers in the United States have sold out to developers whose clientele now see these landscapes as useful for ranchettes and exurban communities (Brogden and Greenberg 2003: 293). In Northwestern Mexico, ranchers find their ejido shares less ecologically viable as individual parcels and ultimately more easily degraded than when the range was communal property (as I will discuss further in Chapters Six and Eight). Degradation, in other words, is in the eye of the beholder and less a deterministic quality that can be assigned to a landscape because of its ability to sustain a particular human activity.

Conclusions: What Should an Arid land Political Ecology Look Like?

First, we must adopt an appropriate unit of analysis. The ejido of Miguel Hidalgo is a large area providing livelihoods for a small community. Yet it is only one small section of a larger watershed where environmental variability is playing out across the landscape, oblivious to jurisdictional boundaries. Desert vegetation communities, loose cattle, monsoonal rainstorms all shift within broad temporal and spatial frameworks that may not adhere to neat categorization of bounded communities like an ejido. Furthermore, the resources that ranchers depend upon move within a larger geographic area--the watershed. This unit of analysis allows us to capture a considerably more relevant sampling of variability, risk, and coping. It also acknowledges the hydrological and land management relationships that govern neighbors (whether individuals or communities) better than singling out San Lázaro as an isolate. The concept of watershed itself also captures an important complementarily between desert and riverine environments in Sonora and the region. Lastly, the watershed sits within a wider political economic context as a transborder area; both beholden to and resisting state interventions from both the United States and Mexico.

Following a cue from older anthropology and cultural ecology, an arid land political ecology should include the proper detailed description of biotic and abiotic elements that more precisely define the "environment" within the study. Like any good ecology, we must seek to describe the components of the ecosystem before we seek to relate those to sociocultural or politico-economic variables. Livestock grazing within the Upper Santa Cruz Watershed may be defined as taking place within a set of biotic and abiotic regimes that generate persistent non-equilibrium dynamics. Livestock numbers are controlled (or at least should be controlled) by frequent multi-year droughts, highly variable seasonal precipitation and areas of high productivity next to areas with lower productivity and less nutritional value from a grazing perspective.

Next, we must seek to define the ecological limits of our study by building on existing--but most importantly current--ecological theory. In this case, non-equilibrium models should come into play in a system where environmental variability makes for extreme difficulty for the ranchers of San Lázaro to assess risk and for aspiring state range managers to assign carrying capacities. Ecological carrying capacities are hence difficult, if not impossible to realistically assign, while economic carrying capacity is often exceeded at great cost as far as risk for the livestock producer and the long-term health of the landscape (a topic for exploring in greater detail in subsequent chapters).

Fourth, we must seek to define the relationships between these limits and our models--and to assign a role for the social science that fills any gaps between them. Watershed conditions are also difficult to model even if hydrologic, anthropogenic, biotic, climatic, and geologic factors are readily apparent. The relationship between these factors and how they relate to the persistent non-equilibrium dynamics at play in range management will become more significant within the context of San Lázaro's history of land management. This history will be outlined in detail in the next two chapters and should provide for context to more recent livelihood struggles. My arbitrary subdivision of upland and bottomland landscapes is significant for understanding and clarifying livestock impacts in the watershed outside of non-equilibrium ecological dynamics. Lastly, contextualizing these watershed-level relationships is critical for eventually attributing values to livestock and landscape management beyond the rather relativistic arguments recently put forth by rangeland ecologists.

Therefore, the role for the political ecological research should be easy to elucidate: why does tenure match or not match environmental conditions in San Lázaro or other parts of northwestern Mexico? As the preceding sections should have illustrated, the ecological conditions that theoretically govern the system of tenure and land use intensity are not stable in a semi-arid system like the Upper Santa Cruz Watershed. The carrying capacity of the range for any given economic activity such as livestock grazing is therefore nearly impossible to assign. This might explain the reasons why ranchers in San Lázaro are not following the cultural logics that Netting illustrated in more temperate systems such as the Swiss Alps (Netting 1981). A persistent issue, however, is that larger, political economic forces are at work in shaping community choices. In this sense, then the political ecology of this arid land agricultural community will describe the historical evolution of tenure in San Lázaro, and then correlate these patterns with environmental conditions. The subsequent chapters will address these concerns directly.

These concerns are largely focused upon the case-study presented herein and beg several important questions. Equally important, what are the results of this correlation or lack thereof? What do those environmental consequences look like in San Lázaro, and in the larger unit of analysis--the Upper Santa Cruz River Watershed? How do these consequences feed back into social, cultural and economic behaviors at the local-level? How do people cope with environmental change in an arid-land ejido? And lastly, what external variables either exacerbate or assist the community members in making appropriate choices?

There are methodological concerns here too that have broader implications for applying political ecology of non-linear environments. Political ecologists have long drawn on their theoretical pedigrees in political economy and cultural ecology to study the intersection of market signals and economic development policies evoke changes in local environments through household decision-making, social organization, and cultural practice. Furthermore, in general, political ecology has consistently applied a historical specificity to its studies that gives us an insight into the long-term political economic transformations that result in contemporary environmental consequences. The non-linearity of the ecological processes on the other side of the equation, however, makes modeling their behavior over the same period of change inherently difficult. Relating the easily quantifiable economic cycles to these seemingly chaotic ecological ones leaves political ecology with an open flank upon which critics have beset themselves (e.g. Vayda and Walters 1999). To address this shortcoming, I will insert the case study of San Lázaro and its watershed within the conceptual framework developed by researchers in the "Resilience Alliance" detailed below.

Ecological Resiliency, Adaptive Cycles, and Social-Ecological Systems

When faced environmental problems—how to make a living from a stretch of dry soil, how to harness a flooding stream, how to adapt to drought—humans often times respond by trying to make things more predictable, mainly through the application of technology, but also through institutions and even cosmologies. After all, human culture and psychology are very much predicated on building a predictable, understandable structure for reacting to what may be perceived as a capricious universe. Referring to the constructivist symbolic underpinnings for behavior, anthropologist Clifford Geertz once called culture a "lens of our own grinding" (1984: 275). That lens narrows our vision to not only what we think is the totality of the problem at hand, but also limits what must be done as a response. Placed into a rubric, these lenses become a worldview that structures much of how humans respond to their environments.

These days, the dominant worldview of human-environment interaction includes the concept of "sustainable development"—that if we can only get the amount of resource extraction to balance with the amount of natural resource production that we will somehow get it right. But what happens when nature presents humans with non-linear phenomena? Given sudden transformations or even gradual shifts in environmental conditions, how do we know that the baseline of "sustainable" is? What makes one group able to react appropriately to this phenomenon? What happens when we can't react properly? The first question is not just one for particular human societies under the microscope of ecological anthropology. It plagues the scholars at the ocular of the scopes themselves too. A persistent problem for ecologically-focused social sciences has been dealing with the non-linear phenomena—the vagaries of shifting climate, fickle hydrology, variable landscapes, and temporary vegetation.

This dissertation is an attempt to evaluate the ways that one small group of humans in northern Sonora respond to just such a varied and explicitly non-linear environment. In so doing I am also turning the microscope the other way and evaluating the means by which social sciences and its allies in ecological sciences have studied environmental variability in arid lands. I will focus particular attention on the matter of how a not insignificant number of cultural ecologists in theory and application have sought to build a worldview based on linearity and equilibrium—even in the face of evidence that this is not the case.

Yet, if I am successful in poking holes in this worldview, what are the alternatives? Alternative approaches based on non-equilibrium ecology are far from conclusive and difficult to implement even by quantitative ecologists. Those applying these theories—managers—have developed a variety of approaches but little agreement on the validity of results. Furthermore, scale is a persistent problem for these approaches, since much of what is happening to human societies occurs at the landscape and even atmospheric level. Larger-scale societal reaction is quite often predicated upon "rational" (i.e., linear) economic logics that may work at cross-purposes to local adaptation and innovation. Lastly, human systems and ecological systems are quite often separated by those studying them because of a persistent reductionist approach.

Beginning from work by Buzz Holling on ecological resilience (1973), a group of scholars in various disciplines have begun to develop a method that seeks to bridge the gaps implied here: 1) non-linear transformations; 2) cross-scalar linkages; and 3) artificial separation between complex, inter-related human and natural phenomenon. Ecological resilience is defined as the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity. Social-ecological systems exhibit thresholds that if exceeded, produce fundamental changes in function and structure and which result in a regime shift (Walker et al. 2006: 13). Like state and transitions theory, these new regimes may be reversible or irreversible depending upon the amount of investment needed. A more resilient system results in greater ability to absorb disturbance without tipping into a new regime. The new "state space" of a particular regime represents a variety of combinations of variables (e.g., shrubs, grasses, trees, soils, fire, and herbivores). Any new regime must have removed or replaced one or more of these variables

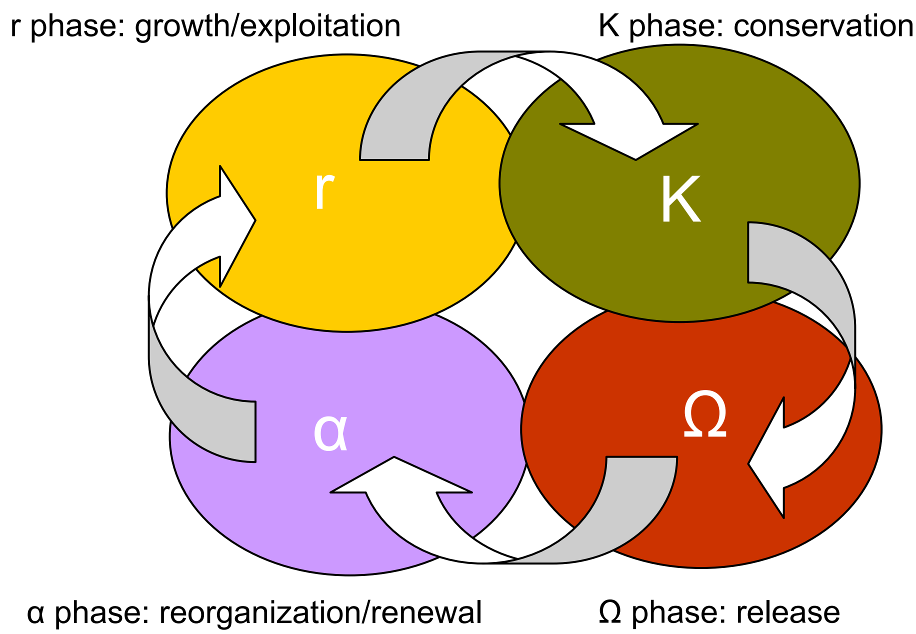


Figure 3.4. The adaptive cycle model. Source: http://www.resalliance.org/570.php

such that the system no longer functions as it did previously (e.g., a scrubland replaces an oak savannah).

The network of institutions and researchers known as the "Resilience Alliance" has developed a set of theoretical heuristics and propositions that rest on the idea of a multi-scalar "adaptive cycle" that explains how societies and ecosystems interact through time (Holling 2001). Adaptation is the capacity of the actors in a system to manage resilience without system-level intent (such as the argument that the market is managed by individual actions) (Walker et al. 2006: 13). The adaptive cycle is presented in Figure 3.4.

The model of the adaptive cycle is a heuristic tool derived from comparative study of ecosystem dynamics (Holling and Gunderson 2002: 49). It was designed to place greater on the processes of destruction and reorganization rather than the traditional ecological processes of growth (succession) and conservation (accumulation and storage). Adding the ecosystem functions of release and reorganization, the model builds a more complete understanding of the process of ecosystem change (and by implication, societal, economic, political or other complex systemic change). Hence the four distinct phases identified in the adaptive cycle include:

1. r: growth/exploitation of accumulated inputs (capital, energy, biomass, etc.);
2. K: conservation of system inputs and a slowing of the growth process;
3. Ω: collapse or release of conserved inputs; and
4. α: reorganization or renewal of the system.

The adaptive cycle moves through two major transitions that may be less obvious in the graphic above. The first or "foreloop" from r to K is characterized by slow, incremental growth, increasing complexity (or connectedness), and accumulation in specific pockets. Where r is characterized by rapid colonization of a frontier or disturbed site, the movement towards a stable system is slow and incremental as complexity increases and inputs are stored or even concentrated in environmental sinks. The second or "backloop" that moves from Ω to α is a much faster process of systemic collapse and reorganization. With rapid release of system elements—stored inputs but also systemic components as entropy dominates—the innovation of new responses to the environment is also rapid. This innovation creates a sort of "re-colonization" of the disturbed system, leading back into the foreloop (r to K).

The authors of the adaptive cycle model are quick to point out that it is only a metaphor or heuristic tool that can be utilized to explain general patterns of development in ecosystems and social-ecological systems. There are no testable hypotheses in the framework. Rather, Holling and other scholars in the Resilience Alliance formulated the adaptive cycle to add dynamics beyond the traditional emphasis on exploitation (through the study of r-strategists) and conservation (through the study of K-strategists) (Holling and Gunderson 2002: 33). The economist Schumpeter (1950) noted that societies (or rather economies) often went through a period of creative destruction once the system becomes increasingly fragile, over-connected, and vulnerable to sudden release. This state Holling termed the omega (Ω) phase. Destruction, however, cannot be a permanent condition; opportunistic agents (species, firms, social movements, or individuals) move into the vacuum and reorganize the now released inputs so that they become available for the growth-exploitation (r) phase. This reorganization phase is designated the alpha (α) phase (Holling and Gunderson 2002: 35). One of the key messages of this model is that capital (resources or inputs) is harnessed in differential fashion throughout the cycle—and move from potential to practical as the agents in the system seek new opportunities or conserve existing resources. Carbon in a rainforest, for example, is released through the harvest of timber, burning of smaller-diameter brush and conversion to pasture while newly important nutrients to the grassland are stored in the new dominant species or erode into local sinks (waterways and inaccessible subsoil layers).

A second, equally important lesson from the adaptive cycle involves its "memory" and "recombinant" qualities. Adaptive cycles may be nested in hierarchies through time and space (becoming tools for looking at cross-scalar linkages like climate, economics, or policy).

Recombination comes from the ability of system agents to harness stored or released capital, testing their new configurations over time. These windows of experimentation open briefly, but the results do not trigger cascading instabilities of the whole because of the stabilizing nature of nested hierarchies. In essence, larger and slower components of the hierarchy provide the memory of the past and of the distant to allow recovery of smaller and faster adaptive cycles. A nested hierarchy of adaptive cycles represents what researchers beginning with Holling (2001) have termed "panarchy." Whereas hierarchical systems are influenced by broad, slow features constraining (or influencing) fast ones beneath them, panarchical systems may have both top-down and bottom-up, features interacting through slow and fast variables (Walker et al. 2006: 13).

The adaptive cycle points to the instability of ecosystems (and by extension, social ecological systems). Instead of a gradual build up of r-strategists to K-strategists as the traditional view of successional series posits, the entire system may go through sudden flips that move into omega (release) and alpha (reorganization) phases. This jibes well with the idea of multiple stable states that may transform down particular pathways or flip once a threshold is crossed. The latter flips are mediated by changes in slow variables (connectedness for example) that then suddenly trigger a fast-variable response or escape (Holling and Gunderson 2002: 35).

Walker and others in the Resilience Alliance have optimistically speculated that social-ecological systems are sometimes able to "transform" themselves when agents recognize a system is untenable for some reason (Walker et al. 2004: 5). In contrast to adaptation, transformation adds new variables and releases others. The transformation of livelihoods from one type to another is a good example while an adaptation involves augmentation of existing livelihoods. In all cases, transformation adds another state (or multiple states available, while impacting multiple scales of the panarchy). Another example of transformation could be the replacement of ranching with wildlife conservation areas by consolidating pastures and removing cattle (vs. replacing cattle with another livestock type). As I will explore later, the San Lázaro case study presents at least two examples of economic and ecological transformation.

Despite its easy answers, the adaptive cycle, however, is not a perfect explanation for system-wide interactions. Other types of patterns can occur in ecosystems and social-ecological systems that alter possibilities or states. Key elements—soils, groundwater, predators, large herbivores, credit—can be eliminated from systems that result in a system that moves into a different, perhaps depauperate state. Researchers posit too that complex adaptive systems may exhibit "leakiness" as some system inputs are overexploited and hence lost to future r, K, or α phases (Abel et al. 2006: 17). For example, overstocking of livestock by ranchers with no other economic opportunities may result in the persistence of semidesert shrublands as soil erosion, changes in soil moisture, and grazing interact to permanently suppress grasses.[1] Complex systems can also become "trapped" in variations of the main adaptive cycle such as the four outlined below.

[1] Technically, this may not be a permanent or stable state as the woody vegetation too can be removed by fire, a series of wet and dry years, as well as persistent drought or even mechanical methods. But the timescales for restoration to the original state (measured in decades) is to long for a rancher who cannot wait for the return of palatable biomass.

- First, shifting from the K to an Ω-phase without the release of sequestered resources. The system maintains its original organization, such as in a democratic election or a forest regime shift where the original nutrients are merely shifted into new dominant woody species (fire susceptible oaks to pines, for example).
- Some systems are unable to conserve or sequester resources after a reorganizing phase, resulting in little new or persistent structure that can withstand major shocks. An area that has converted from rainforest to pasture is an example, as most carbon and nutrients are removed with the harvest and burning of the original woody species. Oxisols left behind can no longer support new r-strategy species.
- If innovation is suppressed, a system may become unable to reorder itself into a new structure. The most poignant example of this is the “poverty trap” in large areas of Sub-Saharan Africa where insufficient capital is preserved to allow new K-strategists to establish a new order. Disorder then persists, resulting in the need for outside interventions (food aid for example).
- Lastly, some social-ecological systems may persist in a state between r and K for long periods of time, buffering their stability by spending resources in adaptive maintenance. The persistence in the United States of the “military-industrial complex” despite the end of the Cold War is an example of a system that spends

resources (money on lobbying and campaign contributions) to maintain itself in the face of omega-phase inducing events.

Operationalizing the Adaptive Cycle

The adaptive cycle, while heuristic and therefore not testable in a classic scientific sense, is still open for evaluation. In particular, it is possible to look for the fit between the metaphor and a case study. In this case, that case study is San Lázaro and the upper Santa Cruz River Watershed, framed within the mid- to late 20th century. But we must break down the model a bit in order to evaluate it more effectively. The most unique properties of the adaptive cycle—potential, connectivity, and resilience—are easily examined in social-ecological systems such as San Lázaro and the upper Santa Cruz River Watershed (Holling and Gunderson 2002: 49). All three are measures of change in a social-ecological system.

Potential can be expressed as ecological, social or economic variables of the system. In ecosystem terms, it may be expressed as the potential biomass, physical structure, nutrients, or successional dynamics of the system. Though Holling and Gunderson (2002) never explicitly use the term, potential is closest to the idea of "natural capital" as articulated by ecological economists (e.g. Daly 2004).[2] In sociocultural terms, potential is expressed and is represented by the character of accumulated networks of relationships, some

[2] While I appreciate the desire of the original theorists (Holling and Gunderson 2002) to avoid reifying the concept by the use of specific terms, in the interests of simplicity, I will use the natural capital in lieu of potential where it seems more appropriate. For simplicity of argument, I will continue to use "potential" in this introductory material.

embedded in friendship, kinship, and membership in institutional organizations. This is similar to some of the varied uses of the term "social capital" by sociologists, anthropologists, and political scientists (e.g., Bourdieu 1986; Jacobs 2000; Putnam 1995). Sociocultural—or rather, cultural potential can also function as a stand in for presence and use of local knowledge to make more locally-appropriate decisions about management of resources (Folke and Berkes 2002: 121f). Lastly, economic potential may be found in the accumulation of knowledge, innovations, and skills. It can also be built by humans' unique ability to craft symbolic hierarchy that allows us to generate expectations or predictions about future conditions. This last form of potential may be thought of as foresight potential (Westley et al. 2002: 115).

Connectedness is a measure of the strength of internal connections that mediate and regulate the influences between internal processes and the external world. It is the extent of internal control that dominant agents have over their inter-system environment. The inter-system distinction is important because it implies that external influences are still possible that can upset the system and tip it beyond a threshold into a new state. With increasing connectedness comes increased cost of maintenance of these conditions. In social-ecological systems, connectedness can be measured by the intensity of control exerted by direct human intervention (for example, in agroecological systems). External and internal variability is controlled as much as possible, usually by the input of energy, subsidies, or technology. More importantly, connectedness can also be correlated with the ability of dominant organisms, species, groups of people, social classes, or firms to sequester and concentrate key inputs such as natural, social and economic capital. The greater the concentration of capital results in less flexible these subsystem elements and hence, increased vulnerability to shocks tends to be a result of increased connectedness. This proposition bears striking resemblance to conclusions of Marxian analysts such as James O'Connor who concluded that modern capitalism is fundamentally a crisis-ridden system because it invariably over-sequesters its primary means of production—natural capital—and thereby limits its ability to deal with ecological consequences (1998: 165).

The last property of social-ecological systems that I aim to examine in the San Lázaro case study is found in the social-ecological system's resilience, or rather, in its vulnerability to external shocks. Resilience is the capacity of a system to experience disturbance and still maintain its ongoing functions and controls. This might be qualified as the system's basic economic and ecological character, household to community-level structure, and basic functionality. For example, given economic or ecological shocks affecting San Lázaro, can people make a living from the agropastoral system, provide for their household reproduction, and continue to live in the community? Tying into non-equilibrium state and transition theory, what are the multiple stable states available for the community? Can it effectively flip between these or does it release its sequestered resources and become disorganized?

These three properties: resilience, connectedness, and potential are in a dynamic relationship over the span of the adaptive cycle. Potential (or capital) establishes what is possible and what can be accumulated or exploited by agents of the system. Connectedness determines the control elements of the system can affect over its trajectory. Resilience determines how vulnerable a system is to unanticipated disturbances that push the system over thresholds. The relationships can be sequenced as:

- Potential (natural and social capital) increases incrementally; efficiency too increases as does system rigidity (connectedness);
- Vulnerability to exploitation and even sudden shocks are gradually revealed, particularly as connectedness decreases flexibility of response;
- Innovation or reorganization of common elements (including capital) pulses through the system, result in testing, adoption or failure of new approaches (Holling and Gunderson 2002: 49ff).

In my case study of San Lázaro, I will focus on the following seven questions that draw out aspects of the adaptive cycle into an evaluative framework:

1. Can we place each period of the community's history within a phase of the adaptive cycle (r, K, Ω, α)?
2. What are the primary forms of natural and social capital (i.e., potential) in the watershed and community?
3. What are the ways that the social-ecological system has exhibited connectedness over the last century, and especially in the last four decades?
4. What were the outcomes of that connectedness with regards to the system's vulnerability?

5. What shocks, both internal and external have tipped the system into omega-phase periods of "creative destruction" (ibid.: 34).
6. What sorts of innovation or reorganization resulted from these omega-phases? Which innovators or other r-strategy actors have taken advantage of these conditions and how did they capitalize on their strategies?
7. What the implications of this reorganization for the community and the ecosystem?

At least one each of these questions will guide an analysis at the end of each subsequent chapter. An analysis of natural capital available to agents within the adaptive cycle has been summarized already in the preceding chapter (Chapter Two). The results of the evaluation of the adaptive cycle in San Lázaro and the upper Santa Cruz River Watershed will be synthesized in the conclusion to the dissertation (Chapter Eight).

CHAPTER FOUR: HISTORICAL POLITICAL ECONOMY OF SONORA & THE SANTA CRUZ WATERSHED

In this chapter, I will describe the environmental history of San Lázaro and the Upper Santa Cruz Watershed and expand upon the political ecology of this arid region, and the relationship between tenure and environmental conditions. Once that history enters the Colonial, early Mexican and modern periods, I will place that it within the context of the history of Sonora and the U.S.-Mexico borderlands. First, I shall contextualize the changes in technologies, tenure relationships, and land use patterns. Second, I shall examine the early and more recent environmental history and elucidate the relationship between shifting tenure and ecological variables to some degree--at least by demonstrating the progress of fit or lack thereof between property rights regimes and local watershed conditions.

Given the paucity of records for variables like rainfall, stream baseflow, and rangeland condition, the ethnohistory of the watershed will serve as some of the best (and only) records of environmental conditions. Because it is so tenuous, it will be difficult to base a strong argument about the region's environmental conditions. Nevertheless, this early environmental history helps to establish an important baseline for build up of natural, sociocultural, and economic capital in the region that will help to fuel the adaptive cycle in the San Lázaro case study.[3]

It is important to point out here that San Lázaro and the Upper Santa Cruz

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[3] Because of its size and difficulty locating historical materials specific to the community, San Lázaro cannot be disarticulated in this brief historical treatment. For this section, I will rely heavily on the record of similar, neighboring communities. Given the strong relationships between these communities and their interconnectedness in a watershed and regional context, this inferential approach is reasonable, necessary, and

Watershed cannot be viewed apart from their historical context of human settlement, economy and policy. This historical context ultimately governed the transformation of nature--land and water primarily from communal to private commodities. The history of the region and its exploitation by different societies also sheds light on the development of technology, social control, and the state of the environment; again, all critical elements of the adaptive cycle. It allows us to glimpse the workings of ecosystems through the lens of people within them, adding great depth to any discourse on the current and potential conditions of land and water use in the watershed--or the consequences thereof. This chapter will outline the broad transformation of the Upper Santa Cruz Watershed and the study site, San Lázaro by Native, Spanish, European-American and Mexican societies.

Periodization

Like many political ecologies--this study is partially focused upon the economic processes that transformed or commodified land and water resources through different tenure regimes. In the Upper Santa Cruz, at least three major economic systems have governed these economic processes whose configuration then had particular outcomes for its riverine ecosystem. The evidence for the economic configurations and eco-hydrological impacts in region are scarce for Native communities in the region. The period of Native domination of the watershed corresponds roughly to 12,000 BC to the entry of Jesuit Missionaries into the region in 1691. I will focus in greater detail on the period of Spanish

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logical.

rule (1691-1820) that laid the foundations for resource appropriation during the subsequent early Mexican (1821-1911) period. As today the Upper Santa Cruz Watershed is divided between the United States and Mexico, it is critical that I also treat the distinct period of history when Anglos passed through the Mexican territory and colonized the U.S. portions of the river basin (1849-1911). The Anglo period, characterized by uneven capitalist development as well as the importation of a foreign cultural ecology, can be directly contrasted with the Hispanic sociocultural configuration. It is during this period that the real "gerrymandering" of the Santa Cruz Watershed took place in the latter half of the last century and continues today. Lastly, the early environmental history of the watershed must include a discussion of the heavily influence of North American capitalist Colonel William Greene who's heirs controlled San Lázaro from 1901 until it was appropriated by the Mexican government in 1959. The history of the ejido birthed from that appropriation will be treated in greater depth in Chapter Five. This periodization is illustrated in figure 4.1 below.

11,000BC	Archaic peoples (Paleoindians) arrive in Santa Cruz Valley: game hunting; wild plant gathering; Use of fire in grassland hunting.	Low population density. Megafauna extinction. Santa Cruz River entrenchment & aggradation.
9500BC	Big game animals decline as the climate warms; Paleoindian adaptation with new hunter-forager livelihoods.	
2100BC	Maize arrives from Mesoamerica; irrigated and dry farming spreads into Santa Cruz watershed.	Canal building. Low population density. Evidence of stream headcutting & entrenchment. Evidence of drought.
1200BC	First canal irrigation in North America established along middle Santa Cruz.	
550AD - 1400AD	Hohokam and Trincheras cultures rise: floodplain-centered irrigated agriculture flourishes then declines.	
1680	Spanish incursions into the watershed; river is named Santa María Suamca. Rancho San Lázaro established by José Vívara Ramos. Hunting, limited irrigated agriculture, & wild plant gathering by Sobaipuris & Tohono O'odham.	Livestock introduced. Watershed territorialized. Population decline & concentration.
1691	Padre Eusebio Francísco Kino founds Mission Santa María Suamca & *reducciones*	
1751	Pima uprising led by Luis Oacpicagigua of Saríc causes wide unrest and the establishment of *presidio* at Tubac.	
1787	*Presidio* established at Santa María Suamca; renamed Santa Cruz.	
1821	Mexico declares independence from Spain Apache warfare depopulates area except *presidios* at Tucson & Santa Cruz.	
1840s-1850s	Americans travel through region as Mormon Battalion (1846) & Gold Rush Argonauts (1849-1851).	Soil erosion accelerated. Vegetation changes. Extinction of large predators Fire ecology changes. Stream entrenchment Decadal drought cycles. Population boom in Nogales & Tucson.
1854	Gadsden Purchase divides watershed into Mexican and U.S. jurisdictions	
1881	Southern-Pacific Railroad links Southeastern Arizona to larger markets.	
1883	Tucson-Guaymas railroad completed through Nogales.	
1890s	Expansion of cattle production in the San Rafael Valley; record of overgrazing.	
1890-91	Catastrophic flooding on Santa Cruz leads to stream entrenchment.	
1896-98	W.C. Greene acquires Cananea mines.	
1901	Cananea Cattle Company organized by W.C. Greene	
1906	Railroad between Nogales and Cananea completed.	
1911	W.C. Greene Purchases San Rafael de la Zanja land grant & San Lázaro.	
1910-1921	Mexican Revolution	
1958-9	Cananea Cattle Company land appropriated by Mexican Federal government Founding of Ejido Miguel Hidalgo on San Lázaro & seven other ejidos.	

Figure 4.1. Historical Timeline of the Upper Santa Cruz Watershed to 1959.

Watershed Changes

The Upper Santa Cruz Watershed exhibits specific--though not unusual--patterns of settlement, land use and water exploitation that may be inferred from historical evidence and expressed across the above-mentioned periods. These patterns follow hydrologic, climatic, ecological and geologic factors in the lands, which have been discussed previously (Chapter Two). Broadly, the evidence supports the following four inferences across the watershed. First, until recently, settlement has been located in locations where the floodplain is broadest, where the stream is most likely poised, and therefore able to overflow its banks regularly. This supported the flood recession agricultural practices, and more successful communities with long-term occupation. Modern communities such as San Lázaro, Santa Cruz, Tumacácori, and Tucson are examples. Archaeological evidence of preceding native communities has also been located in nearly identical locations, if not directly beneath the contemporary settlements. Second, attempts to modify and therefore make more efficient floodplain irrigation have followed similar patterns, in some cases modifying local geomorphology such that stream entrenchment followed, and regular inundation of the floodplains became less frequent. An example of this occurred in late 19th and early 20th century Tucson. In other locations such as San Lázaro, the cause of stream entrenchment is perhaps less attributable to human intervention, though the effect has been identical. Third, a pattern of broad climatic shifts has lead to regular, if not predictable long-term droughts that drove communities into demographic shifts, intensive and unusual water extraction activities, or even abandonment. Lastly, recent human activities in the watershed's uplands--

namely livestock grazing, road construction, and urbanization--have reinforced changes in stream geomorphology such as stream entrenchment or down gradient aggradation.

Prior to the 20th century, evidence of these environmental changes is sparse, imperfect, and in the upper reaches is often difficult to find with same detail of records kept in the middle reach near Tucson. Hence, much of the job of this chapter will be to use what evidence is available from Native, Spanish and American and Mexican archaeology, technology, settlement patterns, oral and archival sources to make inferential judgments about watershed conditions. Researchers excavating floodplain sediments in the middle Santa Cruz have shown that several long periods of floodplain building occurred over the last 10,000 years. These periods of aggradation have been interrupted by at least eight cycles of widespread downcutting of the river channel in the same time period (Mabry 2004:2). Research and synthesis in dendrochronology, palenology and paleobotany give some pattern to the pace of climate change in the region, though on a regional scale that encompasses the watershed.

Prehistory of the Watershed: 400 AD-1691

The early prehistory of the Upper Santa Cruz Watershed is poorly understood. The completeness of the record for the middle watershed, near Tucson, has benefited from many projects to create or widen roads, dig irrigation systems and generally disturb the profiles containing the valley's early material, hence we know more about these cultures but little about what happened upstream. So much of the discussion will draw up downstream neighbors, with the hopeful inference that upstream communities had some cultural or at least material relationships that hold true under my tenuous assumptions about local archaeology.

At the time of first contact with the Spanish major cultures included largely Piman-speakers, concentrated in the Tohono O'odham people in the northern reach of the watershed. During and after contact, however, Sobapuris joined the communities of their Piman-speaking brethren, largely driven by the missionization and series of Spanish *reducciones* or concentrations into Colonial settlements into defendable towns with a significant military presence (Spicer 1997: 119). According to archaeological and historical records, these Piman-speakers were already fairly concentrated into rancherias and depended upon a riparian-based, agrarian subsistence economy, augmented by hunting and foraging in surrounding uplands (Radding 1997:67).

Within the Upper Santa Cruz Watershed, there is evidence of Trincheras culture (35-1450AD) enjoyed a flourishing prior to the establishment of Sobaipuri rancherias although the relationship between the two is not clear. Trincheras sites are characterized by abundant technology including agave roasting pits, well defined fields, *trincheras* (terrace-like fortifications), and carefully engineered irrigation canals. It is likely that the floodplains currently irrigated by the modern canals of San Lazareños trace these more ancient canals. These farming peoples built pit-houses, produced pottery, and participated in long-distance trade routes that extended from western Sonora to Casas Grandes in the east (in present-day Chihuahua). During the eclipse of the Hohokam regional culture from 1375-1450, in period when competition for floodplain agricultural land was fiercest, these people established hilltop towns fortified with rock terraces or *trincheras*. Whether the Trincheras culture was distinct from the Hohokam or a localized modification of it during a period of intense warfare and the collapse of centralized control is still the subject of debate. While the largest concentration of community sites characterized by the *trincheras* was originally found in the Altar and Magdalena River valleys, the Santa Cruz watershed contained sufficient archaeological evidence to extend the type into this eastern portion of Sonora. A fairly large *trincheras* site is located on mesas just overlooking San Lázaro itself.

Other cultural groups present in the area included Paleo-Indian peoples--as witnessed by San Pedro-type projectile points discovered by a local amateur archaeologists--and Athabascan speakers (see Figure 4.2, below). The latter, primarily Apaches and Jacombes provided the greatest motivation for *reducciones* of Sobaipuri peoples from the early 18th century until the late 19th century. Hostilities by these groups proved vexing to Spanish colonial visions of permanent settlements and motivated the garrisoning of *presidios* at key points along the Santa Cruz River including Santa Maria Suamca (Santa Cruz), Tubac and Tucson.

In San Lázaro, a large *trincheras* site found today on a secondary historical floodplain above the contemporary agricultural fields was most likely constructed and occupied during this period. The site extends over at least an acre and contains sites of food storage and processing. No excavation has been conducted there. Hence, little is known about the currently undesignated site beyond Danson's (1946) survey of this portion of the watershed.

Sherd and lithic scatters across the site containing a predominance of Trincheras Polychrome potentially date the surface strata of the site as being occupied between 700 and 1300 A.D. Santa Cruz series red-on-brown is also found on the site, potentially dating from 600 and 1300 A.D. (McGuire and Villapando 1993). The site is directly uphill from the section of floodplain currently cultivated by contemporary *San Lazareños*. Whether this indicates that these fields were cultivated over 600 years ago by occupants of the *trincheras* site is difficult to say, though the evidence would support such an assertion, given that topography allows for this broad valley to form on the floodplain, while directly upstream of the site a narrow canyon restricts floodplain development and large-scale deposition of sediments. A second important piece of evidence is found in organic soil horizons within less than a meter of the surface of a bank cut produced during the twentieth century. These cuts reveal a deep organic layer produced by cienega-like conditions and regular flooding events. It is therefore highly likely as little as 100 years ago that the agricultural floodplain was largely level with a poised stream. Future carbon dating of the O-horizon would add weight to this hypothesis.

Native Economy at Contact

When the first Spanish explorers made their way through the area in 1680, native communities did not demonstrate this peak-population or the same level of social complexity. Rather than large city-state structures found during the Classic period Hohokam or even the fortified hill towns of the *trincheras* period, small bands moved between the valley floors where they raised subsistence crops on the floodplains with ingenious though simple canals and diversion systems, and upland ecosystems where they harvested wild plants and hunted game. Linked by linguistic similarities, several of these communities might trade and work together on common issues (such as boundary disputes with other, un-related native communities).

Spaniards found these communities crude and somehow less civilized than native communities further south. Even 100 years after the establishment of missions in the region, Father Johann Nentvig described denizens of the Pimeria Alta as "living on grasses and rodents" or "in disorganized, impoverished hamlets" scattered across the valley floors and uplands (Nentvig 1980). In Northern Sonora, Opatas, Eudeves, Jobas, and in the upper Santa Cruz, Piman speakers renamed by Spaniards as Sobaipuris cautiously greeted the Europeans. By 1680, when Padre Eusebio Francisco Kino worked his way north towards the Santa Cruz River, Old World diseases, demographic collapse, and social dislocation on a grand scale had already reached these communities (Radding 1998; Spicer 1962).

Like other Piman-dominated areas, land and water resources were communal property for the aboriginal peoples of the Santa Cruz. They were also considered sacred items in Native cosmology-rain, rivers, and storms all continue today to be important elements of Pima and Tohono O'odham cosmologies. Hence, Native cosmology helped to sanctify the cultural landscape. Sacred landscapes are fundamentally indivisible (Radding 1997: 84). Fields were organized around patriarchal leadership, with families controlling specific plots from year to year, while in other areas they rotated among families and lineages, but always on a temporary basis (Radding 1997: 50). In places, the Santa Cruz floodplain was probably crossed with earthen irrigation canals that carried water to the milpas. The ditches were maintained by communal labor from family groupings under the direction of a patriarch. Erosion has eliminated all but a few remnants, such as the ditches observed in several classic-period Hohokam sites upstream from the study area such as the Punta de Agua near San Xavier del Bac (Dobyns 1981).

While water was the most important limiting factor for native communities, entire landscapes held significance to communities of users. Though centuries of mastery of floodplain and *temporal* irrigated farming techniques meant that much of the Native diet depended heavily on cultigens, the surrounding uplands afforded important resources for hunting, foraging and building materials. Mesquite pods (*péchita*), *camotes* (bitter wild squash), yuccas, grasses, agaves, various cacti, oaks, pine, and juniper all provided critical resources for diets, medicines, and materials. Upland game such as deer, pronghorn, rabbits, squirrel, and porcupine all provided important protein sources for Native households.

Control of surrounding landscapes was also a vital part of community security--especially during times of warfare with neighboring ethnic groups. Loss of these areas meant a loss of important hunting and foraging territories that might only be offset by the influx of new technologies and foodstuffs by the Spaniards in the 17th century. Of equal importance, culturally significant places filled upland areas, representing large parts of a local cultural landscape. Rock art and petroglyphs, as well as contemporary places of importance are evidence of this cultural landscape across upland spaces.

Native Hydrologic Manipulation

Dobyns (1981) contends that Piman-speakers in the Santa Cruz and Gila River Valleys were responsible for constructing natural-fiber, mud, and rock weirs for flood control and irrigation that slowed the flow of flood waters and in turn helped produce the pattern of cienegas along the course of both rivers. Radding also notes the use of this technique in Piman areas to the south (1997: 51). These cienegas would then serve as rich deposits of pooled water for drinking or farming, foraging and hunting. Dobyns speculated that labor and ownership of these structures would have been communal, because of the communal nature of the resources they influenced (1981: 45ff). Unfortunately, no documents attest to the existence of such weirs on the Upper Santa Cruz. Given the spotty nature of documentary records, this does not mean they weren't there, or may not have been there previously. One might conjecture that if they had been there, late 17th century disease epidemics moving ahead of Spanish conquest eliminated the populations capable of maintaining them and therefore the structures could have vanished by the time the missionaries arrived in the early 18th century.

Radding (1998: 51) reported evidence of weir-like structures in the Rio Dolores, Rio San Miguel and other streams in Northern Sonora. This hydraulic manipulation is an illustration of the close relationship between Native peoples and their fickle desert water sources:

> *Floodplain farmers improved their fields, drawing on the silt deposited by the swollen river during the summer rains. Just at the edge of the river channel they build living fencerows of cottonwood and*

willow saplings intertwined with branches and acacia brush, creating a permeable barrier similar to the weirs placed in the stream. The fencerows served to slow the rush of the floodwaters and spread fertile alluvium across the milpas. Repeated annual flooding, often requiring the repair of the weirs and fences, left accumulated layers of arable soil. Exceptionally heavy floods, however, destroyed the Indians' system of weirs and canals and tore out established milpas. Native cultivators adapted to alternate cycles of degradation and replenishment of floodplain soils by planting serial rows of living fences, placed at angles to one another along the shifting contours of the main channel. Aboriginal farmers drew their livelihood from the river and--like their mestizo descendants to the present day--perceived their technology as dependent on the contrasts of flood and drought that marked the seasonal rhythm of village life.

In more ephemeral or intermittent systems--streams that flow as a result of local precipitation events--Pimas attempted to establish *temporales* or temporary plantings that might succeed if the rains and the runoff were sufficient in a given winter or summer rainy season. In some areas, farmers might irrigate their *temporales* with water extracted by from shallow wells dug into the floodplain called *batequis*. These shallow wells to ground water were also often used for drinking water by humans and animals alike. *Temporales* might also be watered by diversion structures that carried surface water off of surrounding terraces during storms--thereby enhancing the flood flows during storms and increasing discharge in local tributaries. Whether these subtle modifications influenced long-term base stream flow (by trapping water and increasing infiltration or on the other hand by increasing conveyance) is not clear.

The hydrologic state of the Santa Cruz at contact in the late 16th century or early 17th century is not clear, nor are there reliable accounts of some of this hydraulic manipulation. I can only speculate that, given the recent dating of channel entrenchment and the subsurface organic horizon now visible in the eroded banks that the Santa Cruz River flowed at grade with the surrounding floodplain. Evidence of tree fences, dams, or other structures have now been obliterated by the past three centuries of floods, landscape modification by post-contact settlements, fuel-wood cutting, and climate change.

Spanish Colonial Period (1691-1821)

Europeans may have entered the Santa Cruz Watershed sometime between 1540 and 1542 with the military expedition of Coronado, though records are less definitive than in the neighboring San Pedro drainage. The best-documented entree into the area was perhaps that of Jesuit Father Eusebio Francisco Kino of Segno. In 1691, Kino's military escort Capitan Juan Mateo Manje described and placed the small river--designated the Santa María Suamca (or Soamca depending upon the source)--and surrounding valley on a map that gradually filled in as the Spanish Empire expanded north and westward. Kino and later missionaries constitute the largest source of documentation on the status of the watershed during the early years of European rule. In most cases, diaries, letters and other official correspondence by members of the Society of Jesus as well as Franciscans were the only documentation to last until present. Large gaps still exist in this written record, with little hope of shoring them.

In the spring of 1691, Kino, Manje, and others described the valley as occupied by small *rancherías* of between 80 and 900 persons, scattered through an intensively farmed valley floor that was supplied by a vast network of irrigation canals. The farms produced in these "beautiful, fertile and pleasant valleys" a surplus of corn, beans, cotton, squash, melons, and tobacco (Bolton 1984: 265). In some areas, large cottonwoods provided "abundant shade" for residents and visitors (*ibid.*). The "sparkling stream" of the Santa María Suamca (Santa Cruz) occasionally formed what the travelers described as *cienegas* or marshes filled with reeds and vegetation. Again, although evidence remains a few words carefully extracted from journal entries, the river and watershed supported a population of apparently successful floodplain farmers. This means that in places where the missionaries built permanent structures to minister to the local Piman-speaking Sobaipuris--San Lázaro, Santa Barbara, Tumacácori, Santa María Suamca (Santa Cruz), and Guevavi--the river was probably poised and flowing long enough to sustain crops in the late spring foresummer drought.

Early Spanish conquest, settlement, militarization, and missionization resulted in the establishment of a peripheral frontier economy. Because of a combination of distance, communication, and hostile Native peoples the Upper Santa Cruz—like the rest of the Greater Southwest—was only loosely tied to the heart of the empire in Mexico City, several hundred miles to the south. While the Spaniards utilized unique cultural configurations such as cattle ranches, missions, presidios, and mining camps to appropriate resources in the region, the scale of commoditization and territorialization was small and relatively disarticulated from the centers of economic or political power (Sheridan 1992). This disarticulation meant that governance of resources such as riparian forests and river water was local and inconsistent with Imperial goals. Because few Europeans ventured north to populate this harsh and isolated frontier, demographic pressures on the landscape were light. Donald Worster (1985: 31) characterized Spanish irrigation societies as based on "a local subsistence mode" where "water control relies on temporary structures and small-scale permanent works that interfere only minimally with the natural flow of streams…In such cases authority over water distribution and management remains completely within the local community."

Despite the obvious advantages of Native livelihood in the desert, the self-ascribed Spanish *gente de razon* did not take up such a flexible existence, such as moving between lowland floodplain fields and water sources higher in the mountains or terraces surrounding the Santa Cruz Rivers. Instead, they adopted only selected parts of the livelihood strategy that jibed with Spanish custom and--more importantly--concepts of tenure. Primary among these was alluvial floodplain farming--often by appropriating native fields to do so--while establishing their major settlements close to the river. The largest Santa Cruz mission in the 18th century, Guevavi was constructed on a terrace less than 100 yards from the river's edge. Another example is Tumacácori, a smaller *visita* during the early 18th century, sits within 50 yards of the present-day Santa Cruz River. Spaniards constructed *acequia*s that diverted river water around the entire settlement. Farmers could then tap into the *acequia madre* or mother ditch with sangrias or lateral canals to water their fields within the floodplain. Unlike the shifting cultivation patterns of their native charges, the missionaries and later European settlers were beholden to less flexible patterns of water and land appropriation because the size or shape of the *acequia madre* could not be easily altered once it was dug-at least not without serious labor contributions and major disruptions to agricultural cycles (Rivera 1998: 60).

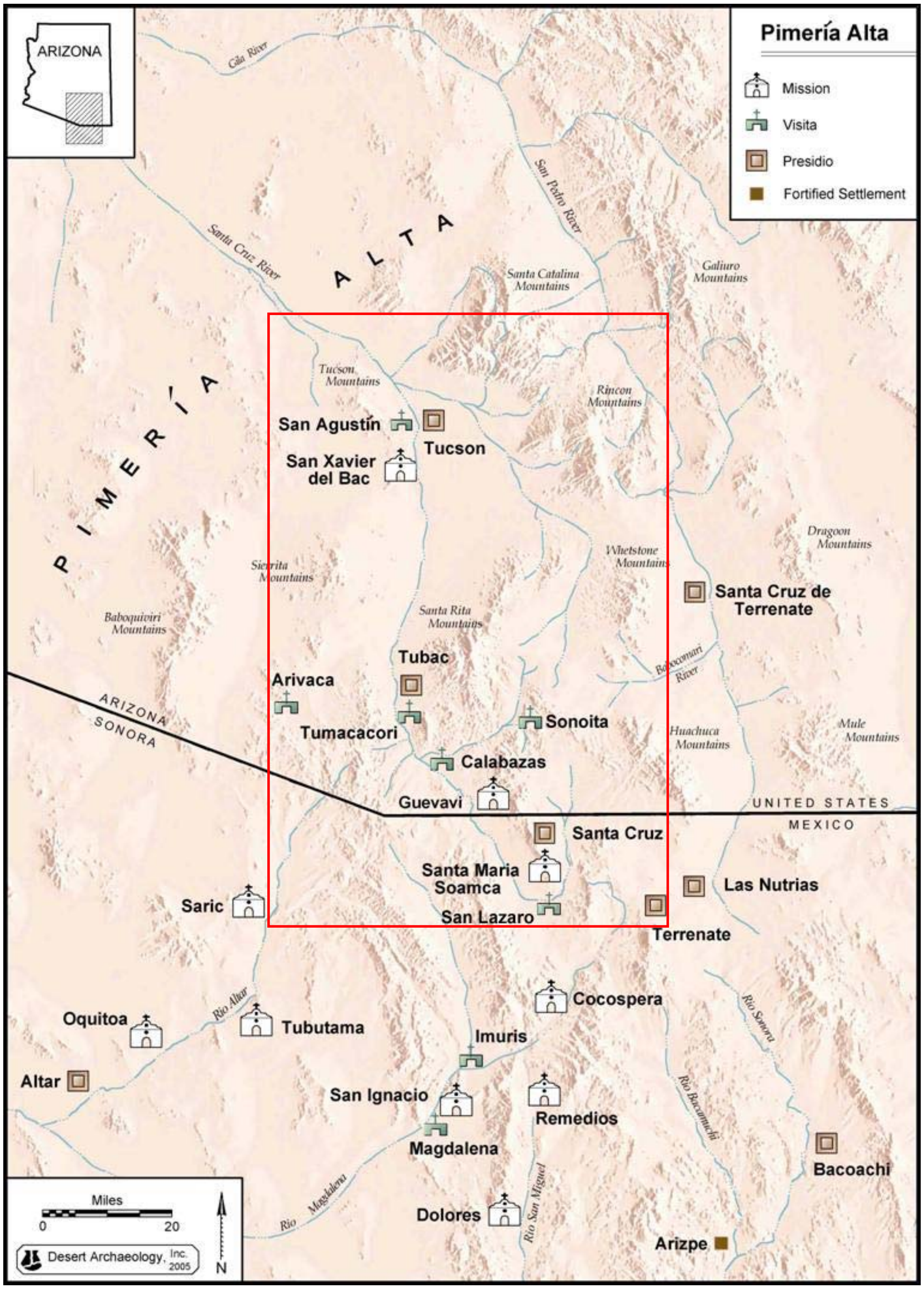

Figure 4.2. Map of the upper and middle Santa Cruz Watershed (red box) and the Pimería Alta during the Colonial Period (1691-1821). Graphic provided courtesy of Jonathan Mabry and Desert Archaeology.

Private Property Comes to the Santa Cruz Watershed

Spanish appropriation of water and land was significantly different from Native traditions. The Spanish brought with them a foreign concept of private property into the local cultural ecology and considered it to be a fundamental underpinning of their *razon*. Furthermore, private property ownership meant lifestyle changes staying to work the fields year after year, despite environmental conditions or seasonality (Meyer 1984:19). Franciscan Father Visitor Antonio Ramos, upon inspecting fields near Tubac and San Xavier commented that "even though at planting time they [Indians] get crops in the ground then, as they are accustomed to wander, they leave them unattended", and speculated that this was caused by "laziness and indolence, which is present in every Indian" (Baldonado 1959: 24). However, unlike later Anglo settlers, the Spanish concept of ownership came with certain constraints on accumulation as well as obligations to provide for the social good of communities. Grants of land and water were coupled with a complex set of obligations that, in theory, could force grantees to share water with Native communities, missions, or military uses wherever their might be downstream impacts of water development; in some cases the water rights came with these kinds of obligations explicitly attached (Meyer 1984:120-126). Not only were grants of water rights tied to responsibilities, but also the nature of the northern frontier labor pool after the population crashes of Native peoples in the late 16th and mid-17th centuries meant that construction and maintenance of irrigation works became communal affairs (*ibid.*). Communal maintenance meant that resources had to be shared as payment.

Much of the substance of Spanish water law was originally derived from successive editions of *las siete partidas*, a famous codification of Spanish medieval as well as Moorish, Roman and Germanic law. In *las siete partidas*, water is acknowledged as both a common pool and private resource. Its fluid nature means it cannot be entirely controlled by a single individual, but the law acknowledges that it can be vital natural capital for individual gain (*ibid.* 112). Spanish colonial law was most successful where it worked to adjudicate competing interests (Parry 1967: 194). While the *partidas* codified much of the communitarian ideals of Iberian Peninsula culture, water was used throughout periods of conquest and conflict as military and social capital, to exercise control over subjugated or enemy populations. The Laws of the Indies promulgated by Don Felipe, King of Castilla in 1543--a direct transcription of portions of *las siete partidas*--helped to transplant these values into the American landscape. Under these laws, water became Crown property to be doled out to petitioners and conquerors alike, or denied to enemies of the Empire (Meyer 1984: 21).

Grants of land and water were used during the Spanish *Reconquista* as well as during the conquest of Mexico, to encourage settlement of frontier areas recently captured. For example, in 1789 the Crown granted some 400 acres of land along both banks of the upper Santa Cruz River to Don Toribio de Otero, former commander of Piman soldiers at Tubac. The grant contained explicit references to access to water for the operation of ranches, farms, and mines downstream-particularly the important new presidio in Tucson and mission at San Xavier (Mattison 1946: 280). However, while the grant itself—like others made during the period—contained these kinds of constraints to prevent the abuse of water, it also commodified the resource, dividing it, along with lands into discrete, marketable assets for gain by grantees as well as the ingredients for taxable products for the Crown. Water became both an important tool of Spanish Imperial geopolitics as well a significant ingredient in the production of commodities for the expanding empire.

The Laws of the Indies recognized that settlement had to follow ecological constraints and so ordered settlements "should be in fertile areas with an abundance of fruits and fields, of good land to plant and harvest, of grasslands to grow livestock, of mountains and forests for wood and building materials for homes and edifices, and of good and plentiful water supply for drinking and irrigation." Ordinance 39 of the same document specifically ordered communities, missions and military installations to site themselves near water that was "suitable for farming, cultivation, and pasturation, so as to avoid excessive work and cost, since any of the above would be costly if they were far" (Rivera 1998: 5f). The upper Santa Cruz River valley seemed to have met with these mandates. It was described by missionaries, travelers, military officers, government officials, and others as lush or fertile with a number of excellent grazing grounds, abundant grass, occasional forests of huge mesquite trees, and a river lined with giant cottonwoods, walnuts, willows, and other riparian species. Jesuit Padre Eusebio Francisco Kino, considered to be the first European to spend a significant amount of time exploring and proselytizing in the area, praised the richness of the valley and its potential, and he believed it had sufficient water, grass, and wood to support a community of several thousand people and livestock.

The 1789 Plan de Pitic (now named Hermosillo, Sonora) further specified the technology and administration of Spanish waterworks. The Plan set out schema for *acequias* and diversions, as well as the division of lands into individual suertes or parcels. Responsibilities for maintenance of the community irrigation works were governed by the size of an individual suerta as well as the overall division of water among *pobladores* (Rivera 1998: 7). Where water became over allocated, pobladores were instructed to petition the Crown-through local offices-to be given rights to new waters and arable lands.

In this way, settlement moved up or downstream along the Santa Cruz and its tributaries, although military concerns along this frontier with Apache controlled territory were foremost in sitting new communities (Sheridan 1995; Williams 1988). For example, in 1774, the Franciscan Father Visitor Antonio Ramos arrived at the then cabacera of missions in the Upper Santa Cruz, Tumacácori in order to see if the mission would need to be further combined with its vistas such as the struggling San Cayetano de Calabasas 10 miles to the south. The Father Visitor wrote:

> …*regarding the union of this pueblo of the visita, Calabasas, with its mission, Tumacácori, there is the inconvenience that, besides the opposition that has been expressed, neither at the mission nor at the visita do they have enough land under irrigation for the combined support. Even though it is true that at Mission Tumacácori with more industry they could provide sufficient irrigation for the support of both pueblos, the constant hostility of the Apaches prevents it* (Baldonado 1959: 22f).

Water, or labor to bring water to irrigate crops, was specifically mentioned as an issue in combining the two pueblos. However, as in other areas along the Apache frontier, military concerns trumped all others.

Dealing with Water Scarcity

Despite the means to define, appropriate, and allocate water, Spanish colonial administration still had to deal with the issue of its constant scarcity, particularly in the Santa Cruz. According to traveler's accounts from the 17th and 18th centuries, the river ran only intermittently and when it did, was difficult to conserve for later use. Ultimately, serious conflict arose over the distribution of the Santa Cruz. The area around present-day Tucson-although on the middle Santa Cruz-serves is a case in point. At least four competing demands were placed on colonial water in this stretch of the Santa Cruz: the Pima village of Tucson, the Royal Presidio of San Agustín de Tucson, the communal fields of Mission San Xavier del Bac, and individual Indian plots of San Xavier. Consistent with the Spanish use of water during the *Reconquista*, water rights were doled out to Spaniards first and foremost-particularly military users, then church users, and lastly to individual Indian users (Meyer 1984: 55ff). While the local clergy fought hard to defend Indian water rights, their position weakened significantly as Apache attacks on the area increased in the late 18th century and military concerns became paramount in the eyes of the colonial administration. By the time of Mexican independence in 1821, European or *mestizo* water users were favored even more strongly, especially as the Sonoran and Mexican Federal government turned on the remnants of the Church in northern Sonora. Water law served only to subordinate the Native people to Spanish, then Mexican rule, in spite of any protections it supposedly afforded.

Hydrologic Conditions during the Spanish Colonial Period

Hydrologic or environmental data from the Colonial and Mexican periods are extremely scarce, particularly during the late 18th to mid-19th centuries. Partly this is due to the break down of Apache-Spanish cooperation in the late 18th century, and the shifting of military forces downstream from the upper Santa Cruz to the middle reach of the river. Much of what we have is gathered by inference or circumstantial data. According to Dobyns (1981: 62), in 1775 or 1776, the commanding officer for the northern frontier, Capitan Hugo O'Connor, recommended moving the presidio from Tubac to Tucson in part because of the lack of water along the upper reach, as well as the availability of wood for fuel and building materials near Tucson and San Xavier del Bac. Clergy and travelers had described the area of Tubac as "pleasant", well forested, and with "abundant water" in 1726 and 1750. Today, Tubac is well watered and forested with riparian vegetation. Hence, we can speculate that this was obviously not the case in 1775 if environmental conditions inspired such a drastic move. We also know that malaria was rampant and that the marshy cienegas existed near Calabasas, Potrero Creek, Buenavista, Tumacácori and other locales in the upper reaches of the river (Bahre 1991: 25). According to dendrochronological data (Fritts 1965: 442), the climate of the Greater Southwest during 18th century was stable, punctuated by periods of intense drought and peak moisture. The later half of the century was characterized by particularly moist decades in the Southwest. A gradual drying took place during the critical period of 1775-1800 when the presidio at Tubac was abandoned for Tucson and as the Apache raids on the area increased. We know little of the other pueblos south of Tubac such as Guevavi and Calabasas-only that by most accounts the settlements and their satellite ranches or farms did not survive the century intact without protection from the Apaches. Environmental data for this reach of the river is found during the mid-19th century when colonization and travel through the region resumed under American reign.

Conflict in the Watershed: Security Meets Scarcity

After the removal of the presidio from the upper Santa Cruz to Tucson, the Upper Santa Cruz lay especially vulnerable to the predations of the Apaches, who raided farms, missions and ranches along the river late in the century. By the turn of the 19th century, all but token populations of Pima or Tohono O'odham had largely abandoned *visitas* like Guevavi and Calabasas. Most moved downriver to join more defendable Tumacácori and Tubac or to communities near the new presidio at Tucson (Fontana 1981). By 1821, even these settlements Tumacácori and Tubac struggled to maintain adequate populations, while the well-garrisoned presidio at Tucson afforded protection to a growing population along the middle reach of the river. Post-independence Mexican settlement of the region remained exceptionally sparse during this period as well, due to continual attacks by Apaches (Mattison 1946: 284).

Further upstream, the community of Santa Maria Soamca (Santa Cruz) went through a similar evolution. In 1698, the community of Sobaipuris was elevated by Padre Kino from *visita* under Cocospera to mission *cabacera*. Kino's reports from the period noted that a large church was to be constructed in the town's plaza and that vestments, furnishings, livestock (horses, cattle, goats and sheep) as well as grains (whether seed stock or for consumption is unclear) were to be moved from Dolores to Santa Maria (Bolton 1984: 355). A priest was never formally placed in charge of the mission, however, until 1732 when Padre Juan Keller, a Moravian-born Jesuit was installed. Keller's stormy relationship with the community and the surrounding *visitas* ended with his death in 1759. Apache depredations plagued the open site along the upper reaches of the Santa Cruz River, while downstream *visitas* San Lázaro and San Luis Bacancos, because of their more protected locations survived with around 800 Indians between them.

Colonial Period Settlement and Ranching in the Upper Santa Cruz

The Spanish missionaries were not the only Europeans to populate the Santa Cruz watershed in the waning days of the 17th century or the early days of the 18th. José Romo de Vivar, one of the first Spanish colonists in Northern Sonora operated a stock ranch at San Lázaro, even before Kino entered the Pimería Alta. Romo de Vivar held property in Cananea, at San Lázaro, and in the southern Huachuca Mountains according to 1680-vintage records unearthed by Kessell (1970: 51). In addition to raising wheat along the Bacanuchi River since the 1670s, Romo de Vivar was the *teniente alcalde mayor* (deputy *alcalde mayor*) with Piman rancherías of Cananea, Cocóspera, and Huachuca under his supervision. Open hostilities between the Empire's military and the Upper Pimans came to a violent head in 1688 at Mototicachi and Tepetales. The violence spread as far north as the San Rafael Valley and drove Romo de Vivar as well as other ranchers from the area. They would not reoccupy the region until the 1720s (Hadley and Sheridan 1995: 18). Don Nicolás Romero ranched a few miles downstream of San Lázaro in the vicinity of the *visita* of San Luis Bacoancos during the 1720s through at least the Pima Revolt of 1751 (Officer 1987: 31).

Ranches or stock raising operations (however primitive) were eventually established near Calabasas and in the San Rafael Valley during this century as well (Hadley and Sheridan 1995:20f). With the establishment of *Reales de minas* (royal mines) in the area, and increased settlement further south in the Magdalena, Cocospera, and San Miguel watersheds, secular Spaniards had reason to push north and establish livestock operations in the ecologically productive grasslands and oak savannahs of the watershed. By the early 18th century, silver mining operations were established in Bacanuche (circa 1655), in the Río Sonora watershed (Spicer 1967: 118). Primitive but demographically explosive gold placer mining operations followed in the Río Cocospera and Río Magdalena watersheds. These latter, more ephemeral operations brought sudden demand for goods and services to the northern frontier of New Spain that, though fleeting, increased pressure for good ranching lands, passive (Native) workers, and military protection (Sheridan 1992: 155f). Hence, the grasslands of the Upper Santa Cruz Watershed would have been quite attractive to cattle ranchers and other stock raisers. Writing in his journal during a late fall, 1697 journey to Santa Maria Soamca, Manje described "pastures full of extensive stretches of grama grass for the raising of large numbers of cattle and horse herds" (Burrus 1971: 335). These grasslands were only potential pasture at the time since Manje reported them empty except for wildlife. Cattle still were not grazing on these grasslands nearly 40 years later when in 1732, Padre

Keller accepted his mission at Santa María Soamca. Keller reported that he had acquired two "oxen" by 1734 and a small herd (actual size unreported) was grazing in the area within a decade of his first appearance in Santa Maria (Kessell 1970: 168).

Keller's arrogant reign at Santa Maria--though long--resulted in some difficult times. The Pima revolt of 1751 was led by Capitan Luis Oacpicagigua, a Piman former officer in the Spanish Army who after maltreatment by the padre demanded that Keller be removed from his post as a condition of surrender (Hadley and Sheridan 1995: 21). This was one of many troubled times to befall the watershed and northwestern most colonies during the mid-18th century. Worst among these were Yaqui and Mayo rebellions in the 1740s, followed by successive lower and upper Pimans in the 1750s as well as armed insurrections among the Seris and 1770s. Perhaps taking advantage of the instability, Apache raiding intensified throughout northern Sonora at the same time. In 1763, settlers in the rich San Luis Valley (between San Lázaro and Guevavi), petitioned Captain Juan Bautista de Anza (then stationed at Fronteras) to allow them to move downstream, closer to the presidio at Tubac (Kessell 1970: 168). The abandonment of what had been rich pasturage that supported "more than a hundred [settlers] with a great number of all kinds of stock" (*ibid.*) showed that security drove decision-making more than ready resources. Further north, greater numbers of settlers in the Santa Cruz Valley and a more pinched topography meant that settlers moving down from San Luis would have faced more competition for land and water resources. Indirectly, the petition and the subsequent movement of the *presidio* from Terrenate to Santa Maria in 1787 showed how control of the watershed was critical for Spanish efforts to retain control over the watershed.

The Church finally abandoned Santa Maria Soamca in 1768 when Apaches attacked the community, destroying portions of the mission church in the process. Burning 13 Pima homes, running off 180 head of cattle and 37 oxen, and vandalizing the interior of the church, the raiding Apaches seemed determined to take down the community. Franciscan father Francisco Roche appealed to his superiors to remove him from the hazardous posting--as he appealed to be reposted since his arrival (Kessell 1970: 49). Pimans left the community for safer areas nearer the presidio at Tubac. In response to the raid, presidio troops stationed in Las Nutrias along the upper San Pedro River moved to Santa Maria. By 1787, the community was officially renamed Santa Cruz as the presidio of Santa Cruz de Terrenate was transplanted there to help defend the missions further downstream. Anchored by garrisons in Santa Cruz and Tucson, the watershed became a stronghold for Spanish occupation in the region, allow more protected, and better provisioned transport into colonized areas of New Mexico and California (Officer 1987: 53).

Apache hostilities, neglect by the declining Spanish Empire and coupled with already sparse, demographically tenuous settlements, however, led eventually to depopulation in large areas of the watershed in the late 18th and early 19th centuries. Communities like San Lázaro, San Luis (Buena Vista), Tumacácori, and Guevavi became ghost towns by the time travelers again mentioned them in the mid 19th century. More protected pueblos--whether by geography or proximity to *presidios*--such as Bac, Tucson, Santa Cruz and Tubac sustained viable multiethnic populations--composed primarily of Spaniards, other Europeans, Pimans, and Apaches. Despite hostilities, some regional centers of ranching persisted, such as Buena Vista, Rio Rico (Calabasas), and Canelo. But other communities appeared (by the gaps in occupation and lack of documentation) to wither--San Lázaro was primary among these. When Couts visited it in 1849, he described it as an abandoned ranch (Dobyns 1961: 16).

Winds of Change: Social History of Sonora from Independence through the Revolution

The sequence of changes in the watershed, including the actors in control of it from the late 19th to middle 20th centuries are a reflection of the larger-scale economic, social, and political changes in Sonora. Many of these changes involved an important economic shift from the eastern sierra to the coastal plains and a concomitant development of cross-border trade and industrialization orchestrated by liberal regimes such as the government of Porfirio Diaz-Ordaz (West 1993: 92ff). A good deal of the transformation can also be attributed to the creation and evolution of the borderlands of Mexico and the United States during this same period. In this section, I will trace the major changes in Sonoran political economy (as a consequence of Mexican and regional articulations). Within that history is the formation of the current U.S.-Mexican border which divided and territorialized the watershed, which I will describe.[4] Lastly, I will discuss overall political, demographic and economic trends in

[4] Avoiding what Heyman (1994: 45) calls the "metonym of the border," I am describing the historically specific evolution of an environment that is a volatile, occasionally violent, more intimately tied to dual political economic processes within both countries, and culturally distinct by merit that its residents have forged long-standing class relationships with each other that contrast with the wider area of Sonora and Mexico. While labor in Mexico is tied to industrial and agricultural centers throughout the country, in the border, it is tied also to those of North America. Kansas, Phoenix, and Washington State have as much to do with economic or

Arizona and North America that directly impinged upon the new regional (i.e., borderlands) political economy.

While the politics of Mexican Independence resonated further south in central and southern states, the northern frontier remained a backwater through much of the early 19th century, beset by persistent problems of Indian-colonist warfare, inconsistent economic ties, demographic collapse, and poor transportation linkages. By mid-century, however, this began to change as elites looked to the north as a useful site for raw materials (minerals), open agricultural lands, industry, and trade with an increasingly prosperous North America. Sonoran political economy in the 19th and early 20th centuries was largely tied to the goals of an industrializing northern Mexico, as opposed to the mostly agricultural south. That difference still essentially divides the country in the 21st century. By the time of Independence, Apache and Seri attacks made settlements and economic activity in the eastern mountains or mountain valleys difficult. Settlements with long-standing history in the region experienced frequent crashes in population as the indigenous warfare and predations made livelihoods insecure (Spicer 1962: 241). Time seemed to stop in the east as it became a cultural, economic, and political backwater by the middle of the 19th century (West 1993: *passim*).

Meanwhile, between 1879 and 1910 the coastal zone of the new state of Sonora was transformed from a string of inconsequential settlements into a major transportation corridor that connected the west coast of Mexico with the United States through Arizona.

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social success of local residents than does Hermosillo and Mexico City.

The transformation moved the coast and interior deserts into the position to dominate the state commercially and politically, especially as they absorbed emigrants from the depopulating sierra and southern Mexico. With this geographical concentration, financial and political capital would become firmly entrenched in places like the port of Guaymas, the costa de Hermosillo, Caborca and the Rio Altar Valley, as well as the Yaqui and Mayo River valleys. Technologically-driven irrigation schemes, both private and later public, brought water to these arid reaches where large scale agriculture thrived. Book ended by Guaymas on the coast and Hermosillo further north, the transportation corridor evolved from a wagon road to a railroad line, to a four-lane highway that ended in Sonora at the border town of Nogales (established in 1884), but connected to the busy transportation hub of Tucson (West 1993: 94f). Hermosillo in the center was designated the political capital in 1879, a symbolic move that relegated the eastern portions of the state to a hinterland status well into the 20th century.

Only the major mining community of Cananea would pose a significant aberration from this geographic trend. Governmental liberalization of export and importation rules during the Porfirato (1877-1911) encouraged the establishment of North American ventures in Mexico, especially in the realm of mining. British and American firms purchased the rights to many abandoned mines in the sierra and utilized new Industrial Revolution technologies to wring the last few tons of ore from their exhausted deposits. But the entry of North American financier William Colonel Greene into the mining business at Cananea added a new dimension to the industrialization of eastern half of the state—and especially influenced the character of the U.S.-Mexican borderlands.

W. C. Greene's Cananea Consolidated Copper Company exploited low grade copper ores in the upper reaches of the San Pedro River Watershed. The mining company became an economic force to be reckoned with, employing 2,250 workers in 1906, just seven years after founding of the company town. The area surrounding the mine attracted almost 20,000 people and made the burgeoning city the largest in the state (Hu-DeHart 1984: 160). The nearby town of Nacozari swelled too with thousands as its copper, silver and gold mines succeeded in making investors rich and managers comfortable middle-class livings. The mines at Cananea demanded the importation of chemicals, equipment, and labor that necessitated a railroad between border towns like Naco, Nogales, and the mine. Also as though responding to the needs of the mines, new arterial roads were graded and eventually paved, which also increased the economic blood flow into the borderlands. Frontier towns like Nogales (and it's nearest economic rival—El Paso) responded the new commerce with increasing infrastructure, expanding demographics, and regionally significant political clout. Formation of the regional borderlands between the new Territory of Arizona and State of Sonora took place over a fifty year period. It began with the expansionist United States and centralist Mexico fighting a mid-century war of attrition that left the latter divorced of two-thirds of its territory. By the time that Mexican General Santa Ana had conceded the Republic of Texas, in the east and Bear Republic (Alta California) in the west, Sonora was cleaved at the banks of the Gila River. The Gadsden Treaty and Purchase of 1853 pushed the border further and established the modern boundary that now cleaves the Santa Cruz

Watershed into two, unequal sections. The succeeding three decades and the last two of Porfirian capitalist development (1877-1910) cemented economic dependency between the Mexican industry, agriculture, labor migration, and culture and the Anglo-dominated north. During this time, Greene prospered and fell in his bid to control the largest copper mine in Mexico, then purchased control of vast rangelands that now constitute much of the San Pedro and a significant portion of the Upper Santa Cruz Watershed.

Out of this milieu, the U.S.-Mexican border emerged as an economically potent new region in Sonora and Mexico in general. The industrialization of the border region was not just a product of Yanque capitalism but also strongly favored by the administration of Porfirio Diaz Ordaz. He laid out the welcome mat to foreign companies by allowing subsoil mineral and water rights to be purchased, and more importantly, beginning in 1894 allowed foreign ownership of greater than 50 percent, exclusively within a 100 mile zone of the border (Gonzales 1994: 651). This effectively altered the geographic pattern large scale investment in Mexico and virtually guaranteed the industrialization of the border in subsequent decades. Like mining, the liberal tax, tariff, and investment policies of the Porfirian regime spurred foreign investment by capitalist James Eldredge of the Atchison Topeka and Santa Fe Railroad in the construction of a rail line through Nogales, linking Hermosillo and Guaymas with Tucson (Mascareñas Sanchez, 1999: 14f). Transportation infrastructure advanced rapidly in the borderlands when compared to the rest of Mexico in the late 19^{th} century as part of an economic convergence between conflictive but generally coexisting neighbors (Martinez 1994: 34).

The 19th century witnessed the establishment of extensive agricultural haciendas that were modified to embrace new industrial age technologies, but utilized 18th century means of social control. In end of the century Chihuahua, strong-arm hacendado families like that of Governor Luis Terrazas Fuentes established a stranglehold on governance throughout the highest echelons of the state. In Sonora too, governors came from wealthy, well-connected agricultural families. Ranching, wheat and vegetable production became important leverage points for new and old money in the northwest. With increasingly better lines of communication and transport, demographically exploding European and American markets opened wide to receive the products that Mexico and its northwestern states could produce—hides, dried or salted beef, calves, produce.

Northern Mexico's cattle industry had attained major importance in the national economy by the eve of the revolution. In 1900, the region was dotted with large haciendas, developed over a span of nearly four centuries, annually producing hundreds of thousands of cattle that enriched northern hacendados and filled ranges in both Mexico and the United States. According to the agricultural census of 1902, the Mexican states of Coahuila, Chihuahua, Durango, Nuevo León, and Sonora contained over one million head of cattle valued at approximately twelve million pesos (or about US $6 million). The industry was aimed primarily at the export market in the U.S.—with Mexican calves filling U.S. feeder-cow demand. Mexican cattle growers were therefore largely dependent upon buyers on the other side of the border. Most attempts at improving cattle production during the 19th and early 20th centuries were directed at adding U.S. stock to the desert-adapted *criollo* cattle that had persisted on Mexican ranges since the Spaniards first brought them in the 16th and 17th centuries. Herefords were introduced by U.S. and Mexican stock raisers at the turn of the century and became fully established (if not mixed with the *criollos*) by 1910 (Machado 1981: 7f). With these improvements, U.S. markets increased their purchase of Mexican animals. Between 1906 and 1909, for example, approximately 150,000 head of Mexican cattle entered the United States. Between 1911 and 1912, the U.S. market absorbed as much as 95 percent of Mexico's exported output in beef (*Revista de economía continental* 1947: 18).

In ranching, like mining and other industries, North American capital was welcomed through a variety of federally-crafted financial openings. Ranches in Sonora became fair game for many different foreign investors—mostly North American—most of whom failed when outbreaks of aftosa[5] and brucellosis closed the border to cattle sales in the early 20th century (Machado 1969: 15). Those that created large economies of scale, imported new breeds, and which utilized vaccinations and other emerging technologies, however, prospered in the years leading up to the Mexican Revolution. It was this environment that encouraged Greene and his financial advisors to purchase the thousands of hectares of land that became the holdings of the Cananea Land and Cattle Company and with it, the San Lázaro division in 1901.

The Mexican Period (1821-1901) in the Watershed

While change altered the main axis of commercial and political power in the new

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[5] Hoof and mouth disease was called *fiebre de aftosa* in Spanish.

state of Sonora, the Upper Santa Cruz River Watershed continued to remain a hinterland, at least until the early 20th century with the entrance of W. C. Greene. Cattle ranching and mining operations in the Upper Santa Cruz continued sporadically under the Mexican government. Mining operations in the watershed itself were small affairs, high in the mountains and hills overlooking the Santa Cruz River, hence did not have significant impacts on water use or quality, except when flood runoff might pass into the stream. They did depend on local animal power as well as charcoal harvested from forested areas, both of which undoubtedly impacted the watershed (Bahre 1991: 32). However, stock-raising was the real story, since the animals and vaqueros were completely dependent upon water resources to make operations economically viable. Pushing north from the foothills of the Sierra *Madre* Occidental and the plains of Sonora, livestock-raisers found the rich grasslands of the Upper Santa Cruz River enticing, partly because of ready water. Frequent Apache deprecations, however, on the herds discouraged many by the middle of the 19th century. In spite of the conditions, the more optimistic of these ranchers petitioned the Mexican authorities for title to lands on which they grazed their herds. Grants were made to the Ortiz brothers at Canoa and Aribaca (modern day Arivaca) along the upper Santa Cruz, while farther south at Buenavista the Mexican government divided the Spanish land grant of Maria Santisima del Carmen into the ranch lands of the Tuveras, Mascareñas, Camou, and Elias families. At San Rafael de la Zanja, the herds of the Romero family ranged over the headwaters of the Santa Cruz River. The Herreras family built their hacienda along Sonoita Creek (a tributary of the Santa Cruz) in the midst of their San Jose de Sonoita Grant (Ready

1973: 4). The powerful Elias family controlled vast holdings near Nogales, given to them originally by Mexican land grant. Most of the grants conveyed a broad array of natural resources to the owners, including "all of its rights uses, customs, servitudes, timbers, woods, pastures, springs and watering places and other things thereunto belonging". But these livestock operations, while having a powerful impact on grasslands and riparian vegetation in the upper watershed, were fleeting affairs (Bahre 1996: 62). Cook and Reeves (1976: *passim*) noted that erosion and stream entrenchment in the Upper Santa Cruz took place during the 1850s, possibly due to previous removal of grass and other vegetative cover near the stream from livestock grazing. However, because the Mexican government was otherwise occupied by war with the United States and while the U.S. worked to secure the area for Anglo-American settlement Apache raids increased in the middle to late 19th century. In many cases, Anglo settlers appropriated lands as they moved into the largely abandoned Upper Santa Cruz Watershed in 1880s.

Ranching in San Lázaro not only withered under the Apache hostilities during this period, when it was found in 1867-68 by J. Ross Browne it had ground to an abrupt halt. He described the state of the *rancho*:

> *Our next camping-place was at the ruins of San Lázaro, an old missionary establishment long since gone to decay. The ranch of San Lázaro is watered by the Santa Cruz River, and is one of the finest grazing regions in the State. As usual, it is now uninhabited. Lying immediately on one of the Apache trails, it has been robbed of its cattle, till nothing is left save the ruined adobe walls of the ranch houses and mission, and the broken fences of the corrals and milpas. At the time the mission*

> *was occupied by the Jesuit priests, San Lázaro must have been in a high state of cultivation. The walls of the main building, within which we camped, show evidences of considerable architectural style. Guardhouses and watchtowers are still to be seen; also the remains of an orchard, with acequias for irrigation, and two large tanks for tanning hides. It was evident the good fathers were not deficient in industry* (Browne 1869: 186-189).

Browne's description of an abandoned ranch and town site held for 49er Argonauts such as A. B. Clarke, who passed the "abandoned village" in May 1849 (Perry 1988: 66), as well William Huff (1850: 4) or James Bell (1932: 51).

Watershed conditions during this period were better documented by these same travelers' accounts. The diary of William P. Huff who passed through the Santa Cruz watershed in the spring of 1850, described the valley near Santa Cruz as "at this point is watered by a fine stream of pure water. The green wheat fields although very small were charming and presented a strining [sic] contrast to the barren, rugged, granite mountains on either side of the Valley" (1850: 4). Huff also described Mexican soldiers fishing further downstream, catching what were described as "small suckers four or five inches in length" (*ibid*.). James Bell wrote that the Santa Cruz lay in a "more desirable place for farming purposes could not be wished for; it has until very lately been under cultivation, the hedges and diches [sic] still remain, and corn stalks are still to be seen on the ground, but hostility of the Indians has stopped all operations" (1932: 50). Bell described favorable range conditions, "the grass here is of several different kinds and of first rate quality. One in particular has a head nearly as large and heavy as a wheat head" (Op. cited: 53). The latter grass probably indicates relatively homogenous populations of big sacaton (*Sporobulus wrightii*). Bell mentioned large "mesquit trees" [sic] lining the banks of the stream that were "twenty to thirty feet high, and twelve to fifteen inches in diameter" (Op. cited: 54).

William Colonel Greene and the Cananea Cattle Company (1901-1959)

Modern San Lázaro began life as a rancho on the far edges of the Spanish Empire, but was abandoned from around the late 18th century until shortly after the beginning of the 20th. For San Lázaro, this new beginning was as part of a massive estate owned by one man--Colonel William Greene, Gilded Age capitalist, and for several decades, the sole proprietor of the town of Cananea and it's giant, lifeblood copper mine. At the turn of the century, Greene began to diversify his portfolio by building the largest livestock ranch in the greater Southwest.

The Cananea Cattle Company, or as it was referred to by its Mexican employees—*la companía*—was founded in Nogales, Sonora on May 10, 1901. The sprawling rangelands contained within it encompassed well over 70,000 hectares of Northeastern Sonora, running along the border from the Sierra de los Ajos east of Naco, into the eastern and southern Santa Cruz River watershed. Mexican law at the time prohibited an individual from owning more than 10,000 hectares of land so the ranch was parceled into divisions of which San Lázaro was the westernmost (Sonnichsen 1974:232).

The effect of the divisions was minimal, however, for this last of the large-scale capitalists, as San Lázaro, was intimately tied to the other divisions on both sides of the border. Since 1901, Colonel William Greene also owned the remains of the San Rafael del Valle land grant straddling the upper San Pedro River in Arizona, as well as the San Rafael de la Zanja grant, encompassing the headwaters of the Santa Cruz River in Arizona. The San Rafael Ranch as it was later called became Colonel Greene's headquarters. From the ranch, the Colonel bred high quality bulls for his other divisions, as well as thoroughbred race horses. Stock was moved freely between U.S. and Mexican holdings, meaning that stock on the San Lázaro division could share parentage with stock from the San Rafael Ranch. Cowboys from both sides of the border collaborated in roundups (*corridas* in Spanish), and administrators consulted with one another across the border at Lochiel. Division administrator William Adams was known to spend a week or two at the headquarters in San Rafael every few months. Mexican cattle were shipped over the Sierra Chivato and the Sierra Elenita into the San Pedro River Valley where they were rested on the Palominas division before being shipped to U.S. feedlots. The scale of the operation was vast--and not seen again in the region. In 1904, Greene's cowboys branded 35,000 calves on the Mexican ranches (Sonnichsen 1974: 232-37).

Greene's system of management and land tenure was reflected in his system for branding cattle. Cattle raised and sold in the United States were branded with OR, a brand that came from several steeldust horses brought from Oregon by his wife Ella Roberts Moson. These horses and the brand that was transferred from them to the entire ranch, stayed in the Palominas division of Greene's property along the U.S.-reach of San Pedro

River. For Mexican stock, Greene simply reversed the brand to form RO. At the San Rafael Ranch, the registered herd bore the brand ORO (Hadley and Sheridan 1995: 128). The mixing of the two brands perhaps reflects the interchangeability of stock reared along the U.S. and Mexican Santa Cruz River. Former employees recall that the thoroughbred racehorses that made the San Rafael Ranch famous were also pastured in the San Lázaro division, just a dozen miles down the road.

Following the death of Colonel Greene in 1911, Charlie Wiswold took over management of the Mexican and U.S. ranches on behalf of the now widowed Mrs. Greene (Sonnichsen 1974). The Mexican ranches remained part of the Cananea Cattle Company under Wiswold until 1958, when the Mexican government appropriated them. Mrs. Greene (who eventually married Wiswold) remained on the San Rafael Ranch until 1932. William Ball lived on and managed the ranching from 1938 to 1959 (Diana Hadley, personal communication, May 10, 2005).

Greene was a careful land steward. The success of *la companía* in San Lázaro depended upon the river and other water sources, which were carefully managed, even as they were often altered by technological innovation. Greene was ahead of his time in ideas about stock-raising. In 1905, he cross-fenced his ranches so that he could take his pastures entirely out of circulation and let them rest for up to a year. He also halted woodcutting on some portions of his property, making the argument with the cowboys that the "land will go with it". Greene experimented with arid-land grasses from Central Asia (Sonnichsen 1974:239).

In 1937, the company built an infiltration gallery (a cistern-like system for capturing subterranean water) in the river just north of the ranch headquarters. This system of tubes, earthen and tanks then delivered water into the *acequia* system that watered the floodplain agriculture. Employees of the company tended to the maintenance of the infiltration gallery, the *acequia*, and the fields for year-round production of pasture, feed, and subsistence crops (milpas in local terminology). Several petroleum-powered pumps were placed at strategic locations to draw on subflows beneath agricultural floodplains, although no record of their installation survives to present. Former employees I interviewed recalled that the pumps were in place by the 1950s when the ranch was last administered as part of the Cananea Cattle Company (personal communication, December 2002).

Greene maintained an interest in keeping erosion to a minimum on his lands. He exalted his administrators to keep cattle rotated in and out of pastures in order to rest them. The Colonel also restricted fuel wood harvesting on his lands, for fear that erosion and degradation would result (Sonnichsen 1974). According to ranchers who grew up in the area or who worked for it prior to becoming ejido members, dozens of cattle tanks fed by springs, arroyos, and windmills were constructed on the San Lázaro division. One tank was large enough to be called *represo* (dam), on an arroyo that ran past the *rancho* of El Cajon, filled with fish, indicating a significant body of water (personal communication, December 2002). The environmental impact of the Greene ranching techniques are not easily teased out of the historical data, although accounts by former employees, Santa Cruz residents, and San Lazareños describe thick growth of tall grasses in higher-elevation pastures (most notably in the present day Milpillas division of the ejido), and of abundant water in the Santa Cruz River. Residents recall more precipitation in the winter months, often in the form of snowfall (a relatively rare occurrence in the last three decades), meaning that during the Greene years the landscape may have benefited from increased precipitation. Climate data recorded during the 1950s from the Arizona reaches of the watershed points to a severe decadal drought that would have run counter to these descriptions. No doubt that despite environmental variability, long-term landscape management was the norm for the North American capitalist, his managers, and his successor, attorney and financier Charles Wiswall.

Oral histories I collected reveal that conditions in the watershed were far different than those of the most recent decades. Local residents described a climate that "*mas helado*" with greater snowfall in the higher country (personal communication, November 2002). Greater snow pack would have meant longer periods of soil moisture availability and recharge for local aquifers or subflows in the river itself. Again, oral histories revealed that the Santa Cruz River itself was less entrenched until late summer flood in 1914 incised a portion between Santa Cruz and El Cajon (personal communication, December 2002). The Cananea Cattle Company installed the infiltration gallery in San Lázaro in 1937, at least 13 years after this event. The gallery provided water to a greater agricultural area, however might have indicated that the entrenchment of the early 20th century led to reduced efficacy in gravity-fed irrigation canals along the floodplain.

Range conditions in the surrounding uplands were significantly different as well. More than one respondent who was raised or who worked since the mid-century in the area said, "*habia mucho mas pasto*" (there was a lot of grass then) (personal communication, December 2002). At least 4000 cattle were raised on these pastures (personal communication, July 2002). Pasture conditions in the San Rafael Valley and Santa Cruz areas recovered from years of overstocking in the 1880s, followed by a disastrous drought and flood in the 1890s. No doubt, flooding in the entire system moved large amounts of sediment eroded from the San Rafael Valley through the Santa Cruz, El Cajon and San Lázaro areas. However, evidence of soil movement and sediment transport in the Santa Cruz or its major ephemeral tributaries in the upper watershed is difficult to assess for this period.

Summary: the watershed through the centuries

The Upper Santa Cruz Watershed has experienced tremendous change in the last four centuries of human occupation, some of these changes were anthropogenic, some were perhaps part of larger cycles of change in the region that reflected climate change, accompanied by hydrologic, geomorphic, and biological impacts (see Figure 3.1). These changes include: grassland proliferation, retreat of oak woodlands to higher elevations, removal of riparian vegetation for farming, construction and fuel wood needs, cycles of river entrenchment and aggradation, overgrazing, drought and accelerated soil erosion. The watershed's human population reached peak numbers sometime in during the Classic Period, then declined through several centuries. Its pre-Hispanic population was considerably larger than the one that Kino, Manje and others described during the early years of Spanish occupation and conquest. From the 18th century onward, population numbers steadily declined under the burden of warfare, political instability and--inferentially--resource over-exploitation. By the beginning of the 20th century, as American and Mexican capitalists purchased the largest areas of the upper watershed, it had been largely abandoned for nearly a century, allowing regeneration of grasslands. They began a period of larger-scale exploitation and population increase. Nevertheless, evidence of severe periods of drought, extreme flood events and increased stream entrenchment followed the new regimes of capitalist exploitation. And except in the case of the San Rafael Valley, relationships between human-impact and non-anthropogenic changes are ambiguous (Bahre 1991; Cook and Reeves 1976). Most significant, however with regards to exploitation and management, the watershed was territorialized into Spanish community holdings, land grants, royal mining operations, and ranches, then reterritorialized and divided between Mexican and American states, weakening any relationship between hydrologic reality and political control. As will be documented in the following chapters, further division of the watershed during the 20th century into communal and then private areas of control continued this trend to the detriment of the watershed's function and maintenance.

Three Centuries of the Adaptive Cycle

These descriptions of fitful human occupation of the Upper Santa Cruz Watershed and San Lázaro at its heart illustrate three important points. First, from the perspective of populations involved in a combination of extensive ranching and floodplain recession and/or canal irrigation-dependent agriculture, during the preceding centuries of occupation, the watershed afforded a considerable potential of natural capital (biomass in the grasslands) and ecosystem services—the most critical being the availability of consistent flood and base flows. Second, historically, the communities in the upper watershed were subjected to extreme variation in linkages with external markets and military protection from hostile groups (mainly Apaches). These variations were more important to the ability for the social-ecological system (SES) to support itself during transformations from r- to K-phases. More significantly, the withdrawal of these externally controlled inputs generated frequent collapses (Ω-phases) followed by reorganization (α-phase). Third, new actors, r-strategists or perhaps even innovators (α-strategists), might have appeared frequently at different points to capitalize on the relative or complete abandonment of floodplain communities, and occasionally the completely new opportunities afforded by the changing colonial, frontier landscape or the technologies available to exploit its resources.

Some of the greatest innovation, however, took place upon initial contact and during the *reducciones* and other social reconfigurations by missionaries such as Father Kino and his immediate successors. At this point, locally-appropriate irrigation practice was developed from a combination of native technology (flood recession and canal irrigation) with European *acequia* design. The management of this new technology also involved new institutions to be developed that managed the tendency for greater or lesser control over socially marginalized members of colonial society. Legal institutions like *las siete partidas* or the *ley de las Indias* had been developed in European settings to assist in the creation of more remunerative conditions for risk-taking colonists as well as homogenous social impact that would maintain peaceful relationships at the local level. However, the local, more synchretic settings were far more important sites for organizational invention.

The movement of new politically and economically powerful entrepreneurs (r-strategists) into these settings also generated expropriation and concentration of social, natural and economic capital. Politically well-connected families, given the rights to extensive land grants and concomitant water rights (even within the constraints of the above-mentioned legal rejoinders to share resources with downstream users), began a fitful process of exploitation and conservation (K-phase) characterized by increased connectedness. The connectedness was manifested in the tight relationships between military postings to protect these enterprises, mining operations that they often supplied, and taxes paid to colonial authorities that supported an enlarged bureaucracy in the core of the Spanish Empire. These K-phases of increasing concentration and connectedness, however, were punctuated by Apache hostilities and open warfare that very often precipitated a series of collapses (Ω-phase). Furthermore, the Empire's troubles in Europe with wars, debt and fierce economic competition generated inconsistencies in military and economic aid to all but the most central portions of New Spain. These problems continued to plague the northwestern frontier through the early Mexican period as the fledgling nation attempted to fight off the aggressive colonization by the United States and its interests. Because of cross-scalar problems like sporadic military protection and lack of consistent economic signals, almost all K-phases from the 16th-19th centuries were remarkably short. The lack of persistence of these individual SESs, however, was not a predictor of future patterns in the watershed during the 20th century, when true "panarchy" conditions developed as economies grew more integrated and social conditions stabilized (with the end of the Apache wars). In fact, the creation of new, highly interconnected capitalist economies along the frontier, such as W. C. Greene's Cananea Land and Cattle Company, created more vulnerabilities that culminated in the creation of the Mexican Revolution and the establishment of new experiments such as Ejido Miguel Hidalgo—a history I will address in the subsequent chapters.

CHAPTER FIVE: EJIDO POLITICAL ECOLOGY 1960-1990

The repeated periods of the adaptive cycle through historical times paint a picture of near constant instability, collapse and reinvention by a succession of societies in the upper watershed. Fragile environmental conditions, human violence and mixed political economic signals meant that life in San Lázaro and elsewhere was brutally difficult from a variety of perspectives. The 20th century, with its abundant technological innovation, increasing economic integration and vastly more intense political signals brought about a series of interesting changes for the communities of northern Sonora. This chapter will discuss the most significant of these and relate the outcomes to adaptive cycles that are more easily observed because of their temporal proximity. First, however, I will set the stage for the creation of the modern agrarian community or ejido at the heart of this study.

The Beginning of the End for *la companía*

The modern iteration of San Lázaro, Ejido Miguel Hidalgo was carved from the remains of William C. Greene's borderlands cattle ranch in late 1958. In political and financial aftermath of the famous 1906 miner's strike, Greene's empire was rapidly fading into memory. Saddled with massive debt from the physical damage of the strike, Greene was forced to make a deal with investors of Amalgamated Copper who then forced him out in late 1907. Once the mines and other assets were sold from under him and the capitalist retreated back to the Northeastern United States where he eventually died in an automobile accident in 1911 (Gonzales 1994: 675).

Prior to his death, the Cananea Land and Cattle Company--Greene's last hold on land in Sonora became a temporary refuge for the man, his family, and a good portion of his remaining assets. But the Revolutionary years (1910-1917) were not kind to cattle ranching or to the Greene Empire. The Mexican Revolution decimated the northern Mexican cattle industry, as groups sought to plunder the ranges in times of shortage, as political revenge, or to boost the war larders of competing factions. Revolutionary General Pancho Villa's tense stand-off and open hostilities with constitutionalist President Carranza forced the *villistas* to rustle cattle from Mexican and U.S. operations within his control. In 1915, three companies within Sonora made requests to sell their cattle to Arizona buyers in order to avoid the worst repercussions of *villista* cattle rustling (Machado 1981: 17). The cattle ranchers, however, were placed between a rock and a hard place. Between 1915 and 1917, triumphant General Carranza's government levied taxes of up to 50% in order to keep cattle destined for U.S. markets within Mexico. Carranza's government also sported a nationalist tendency that bordered on xenophobic, claiming that foreigners—particularly those with land or mineral holdings were "despoilers of Mexico's national wealth." Foreigners holding land or mineral rights were forced to certify them with the Secretariat of Foreign Relations, thus renouncing the protection of their home governments in any dispute that might ensue between concessionaires and the Mexican government (*ibid.:* 24).

The end of the war, however, would lead ultimately to even more unstable times for foreign and domestic owners of extensive ranges. Initially, cattle ranching became an important enterprise for *agristas* who sought to find a place for the Mexican peasantry in the once large-scale enterprise. In 1926, the Mexican government became actively involved in the promotion of agricultural pursuits. In March of that year, the government formed the Banco Nacional de Crédito Agrícola to render aid to agriculturalists and agropastoralists. The law creating the Bank was without precedent in Mexico, largely because it decreed that aid would only be distributed to agriculturalists organized into cooperative agencies—and aimed primarily at *ejidatarios* (*ibid.:* 40). But the quick succession of early post-Revolution governments did not tinker with the social order of the northwest—large estates owned by a single family or firm. All this changed in the 1930s with the election of Lázaro Cárdenas.

The administration of President Lázaro Cárdenas was openly hostile to large cattle estates in northern Mexico. Unlike his predecessors, Cárdenas acted on a closely held belief that the Revolutionary Constitution of 1917 should be implemented to benefit a wide swath of Mexican society that had remained largely unchanged since the war. In late 1935, Cárdenas and his government hinted strongly at a nationwide division of the large estates. The proposed plan was to limit such divisions to cattle-grazing areas and thereby increase the number of landholders in northern Mexico and other pastoral zones. The plan was based upon enforcement of the Constitution's Article 27, which permitted a maximum of 12,000 acres to an individual or corporation.

Such governmental machination forced manager Charles Wiswold and two attorneys of the Cananea Land and Cattle Company to travel to Mexico City to plead the case for all similarly positioned cattlemen. They pointed to the misuse of land by legatees of the

National Agrarian Commission and emphasized the disastrous losses and drastic reduction in productivity that could occur when such limitations were imposed. Wiswold and his companions persuaded Cárdenas to raise the limit to approximately 100,000 acres. At this juncture, however, Cárdenas felt that he had been sufficiently magnanimous and remained adamant.[6] Even with the new, more generous limits, over half of the Cananea Cattle Company lands were temporarily expropriated in 1936, although for less than six months. In March of 1937, Cárdenas compromised with the cattlemen and wrote a federal decree that declared large holding with at least 500 beef and 300 dairy animals unaffected from expropriation for 25 years. There was a catch, however: immunity would not be granted until *agrarista* groups had been satisfied through land distribution. By the end of the year, the Cananea Cattle Company had about half of its recently expropriated land restored. At the same time, the Cárdenas administration declared that it would not expropriate more lands in Sonora (Machado 1981: 54).

This policy and the insecurity it created for large-scale land owners were continued by the administration of Cárdenas' successor, Manuel Avila Camacho. In April of 1943, the Avila administration unveiled *Ley de Inafectabilidad Agícola y Ganadera*, which essentially exempted lands that could support over 500 head of cattle from expropriation provided that the local agrarian needs had been met. The insecurity of the law, like its predecessor, forced many large outfits to invest only cautiously in their operations (*ibid.* 56). Under management of William Ball and Charles Wiswold in the 1940s, the Cananea Cattle Company was typical

[6] Consul, Guaymas, to Secretary of State, December 12, 1935, File 812-62221/37, Record Group 59, National

of this pattern. Even with demand for beef peaking during the Second World War, neither stock herds nor infrastructure significantly improved. Furthermore, an outbreak of the contagious bovine disease, aftosa (hoof and mouth disease) in the 1940s brought cross-border cattle sales to a complete halt. The advantage of the border as a staging area for export beef was lost for nearly seven years.

By the 1950s, the ranches became more of a liability than a benefit to Greene's successor Charles Wiswall as a seven year, severe drought[7] and plunging beef prices forced many ranches out of business. The United States Department of Agriculture (USDA) closed the border to Mexican imports of calves, largely because the drought was driving ranchers in the U.S. into reducing their stock through culling and early sales, thus reducing prices that had been stagnant already. Further complicating matters, from 1947 to 1954, the U.S. federal government sought to eliminate aftosa from its livestock, leading to an embargo on all Mexican imports. While the disease never appeared in Sonora, the embargo forced producers to sell internally, to trim their herds, and to reduce their workforce of vaqueros. In response to the drought, smallholding *serrano* ranchers were already reducing their tiny herds, but without a more lucrative external market for their steers or calves, larger producers quickly followed suit.[8] At the same time, agrarian reform checked rapid redevelopment of the industry. Loans for agricultural improvement went principally to

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Archives, Washington, D.C.

[7] Sonora received only 443.7 mm of rainfall as compared to an average amount of 544 mm in the years of 1949-57 (Yetman, Liverman, and Búrquez Montijo, n.d.).

[8] The government of Sonora, recognizing that the U.S. was an important market for its livestock, banned the importation of new animals from the rest of Mexico and worked hard to create herds that were free of *la fiebre*

ejidos rather than to cattlemen in northern and western Mexico. Private banks, rather than the Banco Nacional de Crédito Agícola or the Banco Nacional de Crédito Ejidal supplied capital to the private landholders at higher interest rates and shorter terms (Machado 1981: 60). With the Mexican ranches now costing Greene's heirs significant sums to maintain but generating little positive cash flow, the company was willing to take the federal government's modest financial inducement and get out. When the lands were finally expropriated the Cananea Land and Cattle Company divisions to form the seven ejidos (see below), Greene's last heirs had reduced their working ranch property to the San Rafael de la Zanja just across the border. While today the heirs still live on in the area, the ranch is now an Arizona State Park.

The lands upon which the ejido would depend had been under some form of human-directed management for centuries. Even during the periods of abandonment when Apache hostilities made the upper watershed untenable by most of the communities, San Lázaro's ranges and water sources were utilized by passing travelers, neighbors who's livestock roamed without fences and entrepreneurs such as Greene who saw sometimes speculative profit in Mexican investments. When this landscape entered modernity through the stroke of a president's ceremonial pen, the landscape was undergoing change due to environmental factors outside of human control. Or if the changes were anthropogenic, the lag time between human activity and unintended consequence was significant enough to make it appear that natural causes were behind the outcome. Entrenchment of the Santa

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aftosa. An aggressive campaign of improvement followed the end of the embargo (Caldéron Valdés 1985: 169, Cruz River had already been underway since 1914, while the decadal drought of the 1950s waxed onward, bankrupting ranchers on both sides of the border and causing the expanding cities of the region to tentatively question their assumptions of plentiful water supplies for their growing populations. Enter into this landscape was a new breed of watershed managers: the *ejidatarios* of Miguel Hidalgo. Their activities, challenges, and adaptations to the watershed over the next four decades are the subject of this chapter and the heart of the research presented here. In this chapter, I will describe the operations of the ejido, an institution that is unique in the history of the Americas. I will also describe the series of obstacles and adjustments that *ejidatarios* would face over the succeeding decades, including economic, environmental, and political moments that would bring the revolutionary idea to its nadir by the beginning of the 21st century. Many of these changes are intertwined and interrelated and will be described as part of a general narrative.

Revolution and Post-Revolution: Agrarian Utopia 1960-1990

The San Lázaro division of the Cananea Cattle Company remained within the Greene Empire until 1959, when the Mexican federal government officially appropriated the seven divisions spanning the San Pedro and Santa Cruz watersheds. This significant stretch of land—totaling over 256,000 hectares—was divided into seven ejidos, each roughly equaling an original division. In the case of San Lázaro, the neighboring Milpillas division was added into the new ejido. These seven ejidos were managed under the umbrella

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organization of the Unión de Sociedades Ejidales de Crédito Colectivo Ganadero de Cananea Sonora de Responsabilidad Ilimitada (USECCGCS), and folded into the existing Confederación Nacional de *Campesinos* (National Peasant Confederation or CNC) on the national-level.

Ejido Name	Watershed	Date Formed	Members	Surface Area
José Maria Morelos*	San Pedro	Feb. 3, 1959	175	52,685 has.
Emliano Zapata*	San Pedro	Feb. 3, 1959	68	20,450 has.
Ignacio Zaragoza*	San Pedro	Feb. 3, 1959	108	32,520 has.
Vicente Guerrero*	Río Cuitaca	Feb. 3, 1959	57	17,126 has.
16 de Septiembre*	Río Sonora	Feb. 3, 1959	132	39,655 has.
Cuauhtémoc*	Río Yaqui	Feb. 3, 1959	171	51,300 has.
Miguel Hidalgo**	Santa Cruz	Feb. 3, 1959	142	42,520 has.
Santa Cruz	Santa Cruz	July 21, 1937	200	11,335 has.
Miguel Cárdenas Valdez	Santa Cruz	July 7, 1981	96	9,065 has.
Adolfo López Mateos	Santa Cruz	Oct. 13, 1981	84	9,115 has.
Álvaro Obregón	Santa Cruz	July 7, 1981	25	3,695 has.
Centauro de la Frontera	Santa Cruz	July 7, 1981	27	5,369 has.
Mascareñas	Santa Cruz	July 7, 1981	52	7,147 has.

Table 5.1. Associated ejidos within the San Pedro, Santa Cruz and neighboring watersheds. * Ejidos in the San Pedro Watershed. **Only ejido in the Santa Cruz Watershed that was originally a portion of the Cananea Land and Cattle Company.

The ejido at San Lázaro, named Miguel Hidalgo, was organized as a *colectivo* (collective) in which all management decisions were made by the *comisariado* del Ejido Miguel Hidalgo (Ejido Miguel Hidalgo Committee) under the close supervision of the federal Banco Nacional de Crédito Ejidal, or Banco Ejidal. The Banco Ejidal became the primary vehicle for credit and capital purchases for the fledgling agrarian community. Ejido Miguel Hidalgo became a formal entity on February 3, 1959 with a decree of reform-minded President Adolfo López Mateos (1958-1964).

Under post-Revolutionary law, the ejido land tenure structure was to remain agrarian with *ejidatarios*--also known as *socios* (members)--given usufruct rights to the community property, which was ultimately held in trust by the federal government. One of the most important principles of the Mexican Revolution was 'land to the tiller,' and until the 1990s, it remained foundation for many of the rules written into the *Ley Agraria* (Agrarian Law) governing land tenure in ejidos, agrarian communities and government designated small private properties. Agrarian Law specified that an *ejidatario* could work his or her own land but could not leave it unused for more than three years or rent it out to outsiders. In theory, ejido land was meant to provide an economic basis for peasant families and should not become an economic commodity. The implied social character of these rights was obvious in that ejido assemblies were the only bodies allowed to transfer rights from one socio to another, and that land sales were strictly forbidden. In practice, however, *ejidatarios* all over the Mexican countryside have found ways to circumvent these directives by illegal leasing, sharecropping arrangements, and covert land sales. The provisions of the *Ley Agraria* governing abandonment were rarely enforced, as relatives worked migrants' plots or guarded their rights in *asamblea*s. Similarly, although the *Ley Agraria* stipulated that *ejidatarios* were not allowed to possess more than one share of community lands, and could only pass it on to a family heir (Nuijten 2003: 477f). Such stipulations however, have found little grounding in modern reality of land tenure in the social sector. Illegal land sales, leasing, non-familiar inheritance all occurred in ejido lands across Mexico (*ibid.* 480).

From its creation, Ejido Migule Hidalgo was integrated into the larger organization, the Unión de Sociedades Ejidales de Crédito Colectivo Ganadero de Cananea Sonora de Responsabilidad Limitada (USECCGCS). The Unión served as a local administrative arm of the Banco Ejido. Ejido Miguel Hidalgo maintained a prominent role in the USECCGCS, contributing several times over its lifetime to the presidency and leadership of the organization. This series of nested organizations kept the ejido in the nexus of political relationships from the local, community-level to the regional, and then ultimately to a federal system of clientalism (Cockcroft 1990: 120). These relationships and outcomes will be detailed further in the subsequent section.

Families and individuals from a variety of locations helped found the fledgling agrarian colony. Centers such as Nogales and Cananea contributed the greatest proportion to the community. A sampling of 81 heads of households taken in spring of 2003 revealed that 33 percent of these heads of household came from either Nogales or Cananea, while neighboring Santa Cruz contributed a full fourteen percent of families to the overall population. Although Sonorans accounted for nearly 95 percent of the total heads of households, seven percent of the heads were born elsewhere (though the majority of these out of state-origins hailing from Northwestern Mexico, primarily Sinaloa and Baja California but also Jalisco, Chihuahua, and Zacatecas).

	Raw	Percent
Total	81	100.00
Santa Cruz	21	25.93
Cananea	15	18.52
Nogales	12	14.81
Hermosillo	4	4.94
Navajoa	3	3.70
Naco	3	3.70
Other States	6	7.41
Total Sonora	77	95.06

Table 5.2. Origin of heads of households in a sample of 81 households in San Lázaro, Sonora. Survey conducted April 23, 2003.

In most ejidos formed during or immediately after the 1930s intensively farmed (i.e., arable) lands were parceled to individual ejido members--usually men. The other dry lands were designated as community range or forest lands. In arid regions of Mexico such as Sonora, these common lands formed a major portion of the ejido--part of a national average totaling upwards of 77 percent of the total area (Reyes et al. 1974: 458). A smaller number of ejidos were organized in collectives or cooperatives where land was divided into individual plots but managed by the entire ejido under division bosses (*mayordomos*). Ejido Miguel Hidalgo, like the other six newly formed communities in the region, was one of these.

Financial Control: *El Banco*

Ejido lands could not be used for securing credit; this was the role of the federal government and its financial institutions. This fact allowed for the creation of a carefully managed but pernicious patron-clientellism in the countryside. Banking was seen as an integral part of the Mexican state's ability to leverage control over rural constituencies. This was especially true within the 1970s, when agricultural credit expanded greatly (Mogab 1984). Agricultural credit was used the build strong corporatist ties between *campesinos* and the state. Even into the 1990s, the Mexican rural finance systems connected well over 3.5 million rural households directly to the state (Myhre 1998: 40). In place since the days of President Cardenas (1934-1940), this system guaranteed a strong base of political support in the countryside for elected officials of the ruling party, the Institutional Revolutionary Party (PRI) (Cornelius, Craig, and Fox 1994). The system of rural credit delivering funds to the masses of *campesinos* all but guaranteed the stability of the dominant post-Revolutionary regime for 71 years by wedding rural people to the state and assuring the production of cheap food for their urban relatives (Barry 1995: 105).

The Ejido Union was organized and administered by the Banco Nacional de Crédito Ejidal (Banco Ejidal), a federally franchised and operated bank designed to administer everything from credit to technical assistance to the "social sector" of Mexico--the ejidos as well as other agrarian and indigenous communities. Since 1926, when the Revolutionary Mexican government became actively involved in the promotion of agricultural pursuits, the Banco Nacional de Crédito Agrícola, along with the Banco Ejidal rendered aid to agriculturalists such as the newly formed ejidos in the San Pedro and Santa Cruz watersheds. The law creating these banks was without precedent in Mexico, largely because it decreed that aid would only be distributed to agriculturalists organized into cooperative agencies and aimed primarily at *ejidatarios* where most subsidies previously supported large operators (Machado 1981: 40).

As mentioned earlier, the ejido credit system assured a highly connected system of control for members up and down the hierarchy. In order to succeed at one level (and thereby gain livelihood for yourself and/or your constituency), a political actor—ejido member, *comisario ejidal*, ejidal union, Banco Ejidal administrator—would need to give fealty to those higher up in the organization. Only those actors higher up in the chain of relationships profited sufficiently to enrich themselves, especially officials in the federal government. Though virtually not recoverable in the case of the USECCGS, there were hints that corruption was common, the strongest indications coming from the tale of a former bank official who watched a select few of his colleagues grow increasingly wealthy from their relationships with seed, fertilizer, and farm equipment dealers (personal communication, June 2003). Another indirect signal of corruption was the fact that when the ejido finally broke with the Banco Ejidal in 1988, almost all of the important bank records—titles, transfers, receipts, accounts—were disappeared or burned (personal communication, July 2003). Hence, decision-making became highly centralized or top-down in nature, a characteristic of post-Revolutionary Mexico until the mid-1990s.

Credit in Ejido Miguel Hidalgo has been a contentious issue, driving local politics and building internal and externally-focused resentments. Between 1960 to 1975, Ejido Miguel Hidalgo received credits totaling 8 million pesos from the Banco de Credito Rural del Nortoeste, S.A.—the local arm of the Banco Ejidal. At the same time, profits from the ejido's various enterprises did not keep pace with these debts--the total profit as of 1975 was only 1.5 million pesos. The on-going debt/capital ratio for the ejido consistently exceeded one, meaning most principal was not repaid and interest continued to accumulate during the entire period (Garduño and Gonzalez 1976). Much of this debt was spread among various operations, including cattle production, the apple orchard, building construction, and equipment. The debt was also disbursed and individualized at the household level—leading to some important consequences for the ejido.

Rural credit in Mexico was and continues to be more fungible than credit in the United States. It plays an important role in sustaining month-to-month operations of many rural Mexican households. If converted to cash, a loan may go to pay for educational expenses, household appliances, vehicle repairs, medical emergencies, or improvements in the home. *Ejidatarios* in San Lázaro frequently used their loans for these types of purposes. Receipts describing the purpose of each *adalenato* or advance loaned by the ejido from its annual credit allocation are found in disorganized boxes now stored in the community's dusty archives, the old manager's residence usually referred to as "la casa Greene" because of its ties to the capitalist. A sampling of these receipts by the author revealed a variety of needs: vehicle repairs, a purchase of new chickens, travel expenses to Guadalajara, sending a daughter to secondary school in Cananea, an emergency dentist visit in Hermosillo. This pattern of expenses and debts may reflect what Heyman (1990: 348) called "waged life-course" where cash is the key to subsistence rather than staple crops or household labor. Economists call this consumption credit to distinguish it from production credit.

While they may be critical for household reproduction, these uses of credit were ignored by rural credit programs that claimed their assets were going to create or boost production of agricultural commodities. So while the bureaucrats in the banks could claim successes on paper, the individual households who took on debt to pay for costs that were not otherwise covered by profits from ejido operations suffered. The result was that collective debt became private for ejido members. The banks were rewarded for the collective success, not the individual. Even if the community showed a success on the books for the bank officials, the community also paid a cost in more impoverished households who had to work longer to pay off the loan advances. These loans were also expensive for the families that used them. Interest rates for rural credit were not as artificially low as intended by their lending institutions. During the 1960s and later 1970s, credits administered to the social sector jumped from 12 percent to 34 percent as the federal government battled both a severe imbalance of trade at the national level, and as the currency fluctuated through several sudden devaluations (Adams 1997: 56). In the 1980s, the credit situation became even more critical for families as individuals could only apply for credit without the full assets of the ejido to count for collateral. According to a former ejido president, credit to purchase a Hereford cow went from 16 percent to 76 percent in the period of 1989-90. Completely aware of the wider political economic context, the former official offered that it was "symptomatic of a national financial crisis at the time" (personal communication, September 2002). *Ejidatarios* often simply curtailed other activities during period of soaring interest rates. Another former official noted that at times of high interest rates: "*casi nadie solicita creditos, porque los intereses son muy altos y muchas veces las pequeñas empresas solicitan un credito y no alcanza para cubrir las responsabilidades anuales y muchas veces sacrifican el* *presente, para esperar algo en el futuro*," (hardly anyone would ask for credit because the interest was very high and many times small businesses would request credit and they wouldn't cover their annual debt and many times sacrifice the present and hope for something in the future) (personal communication, July 2002).

These cycles of financial crisis increased livelihood insecurity for those without the means to pay for some household expenses. By creating dependency upon cash—whether from loans or other means--the waged life course too built financial vulnerability into the agrarian communities by limiting the options for rancher-farmers. If one did not make sufficient money in a given year, the household had no choice but to find whatever means were available to repay the debts incurred in previous seasons. Coupled with environmental risk, this has been an untenable situation. Overall, the financial control of the community by the banks was to generate an indirect—and thus pernicious—dependency. The economic resiliency of the community suffered, particularly without the resources to innovate, take risks, or adapt to ecological change.

Technological Control: The Green Revolution

Ejido Miguel Hidalgo was born into a period of tremendous change in Sonoran and Mexican agriculture. The ejido provided a blank slate on which to build a modern agrarian utopia that, along with the other members of the USECCGS, was envisioned as a model for ejidos in Sonora. With this vision in hand, the ejido leadership and its financier—Banco Ejidal set about an ambitious plan to modernize its agriculture. Between 1960 and 1968, the ejido was issued plentiful credit to establish an intensive pasture-based dairy in Agua Zarca (a *rancho*), to install new cattle tanks and windmill pumps throughout the rangelands, and to plant a new apple orchard with "Red Delicious" hybrid trees. The floodplain *acequia* system was cleaned and maintained. More importantly, new cattle varieties—Zebu, Hereford, and Charolais—were introduced to replace the older stock left by *la companía* (personal communication, July and September 2002).

The ejido's creation was fortunately coincident with the explosive growth of new agricultural modernization schemes in Mexico and especially Sonora. While Mexican agriculture in general languished after the Mexican Revolution, parts of it still continued to receive governmental and private largess in the form of capital, credit, and technological innovation. While during the reign of President Lázaro Cardenas (1934-1940), the peasant farmer and the *ejidatario* benefited from federal agricultural policies, the remainder of the post-Revolution governments to present saw small-scale agriculture as an impediment to progress and modernity. Following Cardinas, under the administration of President Avila Camacho (1940-1948), the emphasis shifted toward agribusiness productivity, which was viewed as a necessary adjunct to the post-war industrialization program of Mexico. Cheap foodstuffs would feed cheap labor in the cities. Instead, beginning with the Sonoran Dynasty of presidents Obregon and Calles, and solidifying in the Avila Camacho years, federal investment was aimed squarely at the largest, most capitalized producers (Stavenhagen 1975: 225f).

For example, in the area of coastal Sonora known as *la costa de Hermosillo*, large-scale agriculture received indirect subsidies in the form of federally supported irrigation infrastructure and other technical assistance. The *costa* also saw the construction of a major dam on the Rio Sonora and groundwater pumping wells installed in across the coastal plain (West 1993: 94). Electricity or diesel to the power these pumps were provided at a subsidized cost from the federal government. In the meantime, an ambitious program of genetic and other technical investment focused on the region's wheat farmers. A mixture of private (primarily from the Rockefeller Foundation) and public capital (primarily the U.S. Agency for International Development, and the Mexican government), often working in tandem, supported the Green Revolution. With the major centers of study placed along the coast of Sonora (wheat experimentation in *la costa de Hermosillo* and corn research in Ciudad Obregon in the Río Yaqui delta), the region's large-scale agricultural production boomed. The technological packages included subsidized pesticides, fertilizers and even capital equipment such as tractors and harvesters (Wright 1990: *passim*). Credit, the fulcrum of agricultural enterprises large or small, also flowed freely to producers in these agricultural enclaves. Unlike *ejidatarios* such as those in San Lázaro, well-capitalized ventures could count on easy access to less restrictive private loans. Quite often, the kinship of farmers played in, as relatives of the largest investors in Sonora’s banks owned some of the largest agribusiness firms (Carter Duvall 2002: 156f; West 1993: 105).

The program of technological investment was not limited to the coastal plains but also moved inland to the livestock ranges of the Sonoran uplands and the Sierra *Madre*. Sometime in the late 17th century, adaptable, tough, but lean *criollo* cattle—closely related to the Texas longhorn—were introduced to Mexico by colonial Spanish, where they formed the economically crucial horse-and-cattle complex that harnessed the grasslands of the Sierra foothills and lush wetlands in the valley floors (Sheridan 1988: 28). The cattle were introduced to Mesoamerica as early as the conquest, but more specifically, the 1691 accounts of Padre Eusebio Francisco Kino indicate that cattle were brought into the Santa Cruz watershed. In the 1940s, a persistent outbreak of hoof and mouth disease among Mexican and American cattle in Chihuahua and Texas forced the governments of both countries to close a lucrative market link for almost a decade. The hardy, lean *criollos* took the blame.

Like other Green Revolution technologies, "improvement" of Mexican breeds of cattle was perceived as the solution to this problem. New, European breeds of cattle were introduced to the Mexican northwest beginning in the 1950s. The irony of this was that Mexican or Spanish *criollo* cattle were largely resistant to the European disease. It is now well known that by introducing European cattle into Mexico after the First World War, Mexican breeders inadvertently brought the disease to North America. The French Charolaise was among the first of the European breeds to be reintroduced into Mexico in the 1930s. A young Mexican industrialist, Jean Pugibet who had served in France in the First World War, brought some of the French cattle to his ranch in Mexico (Oklahoma State University, 1995).

Other European breeds made their way into the Mexican bovine gene pool. Some of these had even been there—and in the Santa Cruz Watershed—before the advent of the Green Revolution. Herefords were also introduced prior to the advent of the Green

Revolution. In fact, it was none other than William C. Greene who was credited with bringing the hardy cattle to northwestern Mexican ranges--San Lázaro among them (Oklahoma State University 1995). Cattle breeders know Herefords as the "great improver," introducing rapid growth and lean meat production to longer-maturing, more robust breeds. In early 20th century Mexico, only well capitalized ranchers such as Greene could afford to introduce these cattle into their herds. But by the 1950s, Hereford stock, along with Zebu (a South Asian breed) and Charolais stock began to appear in ranches with some government assistance or sufficient capital to purchase a few breeding animals.

The introduction of new cattle lines meant, however, that range conditions needed to be modified where possible--this was particularly true where forage was scarce along the foothills of the Sierra *Madre* and in the driest portions of the Sonoran upland plain between Hermosillo and the border. Breeds that were better adapted to the sparse forage of the uplands—*criollo* cattle—did not match protein gains of more modern European breeds. But introducing these larger, faster-growing cattle lines meant that new irrigated forage needed to be introduced as well. The answer for Mexico was an aggressive, fire-adapted South African bunch grass, *Pennisetum ciliare,* also referred to by its common name, buffelgrass. Since the 1970s, buffelgrass has been seeded in large quantities across the landscape, usually after chaining or a process referred to in Spanish as "*desmonte*" removed existing Sonoran desert vegetation. According to remotely sensed data collected by Franklin et al. (2006: 66), the total amount of land converted to buffelgrass pastures increased from 7700 hectares in 1973 to over 140,000 hectares in 2000. To keep these pastures of buffelgrass more productive and palatable longer, irrigation systems were placed in the most capitalized ranches. Most of the water for these systems was extracted from groundwater deposits--and given the cheap subsidized electricity supplied by national utilities, cost was less a factor than cash to purchase the pumps, piping and labor. But small-scale ranchers have not been able to afford these kinds of improvements. Like the pattern of development on *la costa de Hermosillo*, large, private cattle ranches in the Plains of Sonora and in some upland valleys in the foothills of the Sierra *Madre* Occidental have succeeded in tapping resources offered by international lending institutions such as the World Bank via the Mexican government while ranchers in the social sector have languished (Yetman and Burquez 1998; Vasquez-Leon et al. 2003; Vasquez-Leon and Liverman 2004). With more access to technological resources and capital to reinvest, some cattle ranchers of this type have even diversified into other livestock--significantly, pig farming (Vasquez-Leon and Liverman 2004:28) which is now the fastest growing percentage of Sonoran agricultural production. In southern Sonora, however, large-scale ranchers have utilized their access to credit for little more than an cash machine, clearing land, seeding it with buffelgrass to show improvement, and then abandoning the operation (*ibid.*:26).

San Lázaro, however, sat on the sidelines of a significant leg in this technological race. The climate was too cool for buffelgrass pastures. The community, like many other ejido operations in the Sierra, was also insufficiently capitalized to take advantage of the expensive process of clearing and planting that is required of the new technology. As of the mid-1990s, the cost of clearing land was U.S.$125 per hectare, while separating the new pastures through new fencing would run at least U.S.$1,200 (Yetman and Burquez 1998: 84). Furthermore, the ejido could scarcely muster the extra water to irrigate these pastures, nor would the bufflegrass be a reasonable substitute for some of the protein-rich native grasses that cattle had fattened on for the past century. The logic could never pan out in either an ecological or economic sense.[9]

Cattle breeds too were sometimes just within reach of the ejido and its ranchers, though not all improvement programs were consistently applied to ejidos like Miguel Hidalgo. Hereford cattle, already introduced to Mexico through William C. Green and Cananea Land and Cattle Company had been improving local breeds since nearly the turn of the century. In fact, Herefords were the primary breed in the uppermost reaches of the watershed--the San Rafael Valley (Hadley and Sheridan 1995: 112). American cattle often found themselves across the sometimes poorly fenced line. The results are more fluid breeding patterns than those of carefully controlled areas in the central portions of Sonora. Charolais, the massive French breed were introduced into the region in the 1920s through purchases by Greene and his manager, Charles Wiswold. The main exception was the introduction of the South Asian Cebu (or Zebu in English) breed. These large, drought-hardy animals were introduced in the 1960s, shortly after the ejido had been created by the Mexican Agricultural Ministry (at the time referred to by the acronym, SARH--Sectretaría de Agricultura y Recursos Hidráulicos). The Cebu added size and weight to criollo cattle, and drought-hardiness to more European breeds.

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[9] Although the University of Texas A&M is developing a cold-hardy variety of bufflegrass for eventual

So while the Green Revolution was both a product of and benefit for the heart of Sonora, the rural hinterlands of the border like San Lázaro and the Upper Santa Cruz Watershed felt only the economic after-effects of the massive undertaking to the south. In ranching, the impacts were seen in the shift of private and governmental resources to the more capitalized ranches of the central plains and the south. In more intensive agriculture, the direction and flow of these resources have helped to shift the pole of regional development towards the more intensively farmed regions of the coast. Ejidos on the agricultural hinterlands instead adopted niche markets like apples (in San Lázaro and Santa Cruz), subsistence crops for local consumption, and in ranching areas, cow-calf operations that supported larger feedlots and ranches in the interior or, more profitably, in the United States.

The last of these "niches" has been the most important exception to this geographic distribution of economic development resources. The Mexican government, through the Agricultural Ministry actively encouraged the small holders of the hinterlands to produce feeder calves for interior or American markets. These smaller calves are raised on the ejido lands to a yearling status and then sold. This is generally a risky and less remunerative business proposition than the production of a fully-grown steer, largely because of the temporal constraints on raising a good calf quickly rather than an adult animal. A healthy calf will grow to saleable size within 8-9 months, beyond that time and the animal is considered to be "adult" in the market, and less valuable to the feed lot market. Beef steers

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distribution in the Unite States, making the grass a possibility for colder areas of Mexico too.

or dairy cattle were raised on the more capitalized ranches of interior Sonora where they might profit from improved pastures of buffelgrass or other exotic plants (Camou Healy 1991: 6; Yetman and Burquez 1998: 74). Breeding is important to the success of cow-calf operators. Massive weight gain in young sale calves is important but not as critical to success as a combination of factors cattle buyers will respond to in making offers. Other traits are equally important to commanding a higher price. These include: lack of horns, deformities and wounds, plus general good health and record of weight gain. Hereford and Charolaise cattle provide the greatest weight gain with the few horns in yearling calves, while Cebu phenotypes provide good health under drought conditions (Oklahoma State University 1995). For this reason, technological improvement of cattle herds became a concern for SARH and ejido calf-producers. While Herefords grazed on the ejido's lands even prior to appropriation of the Greene properties, Charolais were re-introduced in the early 1960s, and the Cebu genes were added through breeding programs in the 1970s and 1980s. According to a member of a non-governmental organization active in the community, cattle improvement continues to be an important project in San Lázaro herds (personal communication, May 2006).

The Green Revolution helped to shift the poles of political economic power to the coastal plains and in so doing, produce the economic hinterlands of the Sierra, in which San Lázaro sits. While the flow of resources is towards the centers of Hermosillo, and the valleys of the Yaqui and Mayo rivers, the ambitions of technocrats from that era to this day still see in the ejidos like Miguel Hidalgo a place for the application of new technologies of power through cattle improvements and the application of other schemes such as fruit, dairy, and other agricultural products. But the fundamental shift in power from east to west that took place in the 19th century has worked against these projects. Only the watershed's proximity to the U.S.-Mexican border has facilitated the success of some market options such as feeder calf production.

While the geographic and economic impacts of the Green Revolution were important to the development of the community of San Lázaro and the entire watershed, the regional ecological impacts are still being felt. From the perspective of the adaptive cycle, the technological innovations increased in the coastal areas, with some teleconnections into the Sierra hinterlands. For example, new crop varieties, cheaper local food production, and new cattle improvement programs spilled over into improvements for the Santa Cruz Watershed's winter vegetable production and cattle ranching operations. The improvement of cattle and the ranges have yielded greater "potential" for or economic and natural capital for local ranchers. While many of these activities were originally promulgated by the government originally, in the form of Sonora's Fomento Ganadero (Cattle Ranching Development), the improvement program has since been transferred to the state cattle grower's union. While the federal and state government tended to be the sole provider of resources, the switch to private ones has helped increase the cattle growers' social capital in the long-run. The increased communications via roads, telephones, and rural electrification increased ecological "connectedness" for the whole of Sonoran society. The build up of social and economic capital in the coastal areas meant a shift in orientation of the Sierra hinterlands towards financial and social centers like Obregón and Hermosillo. The Green Revolution was accompanied by increasing levels of education (though the relationship is tenuous—it is at least concomitant) and especially in agronomy and engineering. While few ranchers in the ejido could pursue advanced degrees beyond middle school (*secondaria*), some of their children have managed to leave the community for degrees in Hermosillo and elsewhere in Mexico.[10]

Control of Land and Water Resources during the Ejido Period

Land and water resources in San Lázaro adhere neatly to Robert Netting's (1981; 1993) hypothesis about the continuum of tenure and intensity of cultivation. Individual tenants or households hold de-facto private title to floodplain agricultural lands where intensive production takes place. On the other end of the spectrum *agostadero*, or rangeland that is extensively utilized by cattle is a more communally organized resource. This is also consistent with Tom Sheridan's (1988: 189) contention that the nature of the resource determines the social organization of production as much as the political and economic webs in which rancher-farmers are enmeshed.

During the ejido period, land was divided into three major categories, depending upon use. The first two, though divided into distinct *potreros* (pastures) *agostadero* (range land) was communally managed and nearly universally grazed. Several of the *potreros* totaled well

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[10] By my estimate based on survey data cited previously (see Chapter 1) and personal interviews, between 1968 and 2002, at least 16 youth out of 142 total households have gone on to *la prepa* or high school and consequently college at the associates level, with one college-educated agricultural engineer who did not return to San Lázaro but who found work with the Cattlemen's Union in Hermosillo.

over 100 hectares each, and cattle were moved between them depending upon the season and the stage of live for the animals. During calving season, cattle were placed in richer pastures to accommodate nursing calves and cows, while in the fall (after the summer rains), animals were moved to lower elevation *potreros* to fatten the yearling calves for sale. In keeping with the initial period of *colectivo*-style management, many animals (or cow-calf units) were even moved between the seven different ejidos. This often created tensions between ejidos as animals were moved without the full consent of ranching families. According to one old-timer, only the promise of equally distributed meat kept some families from full-scale mutiny (personal communication, July 2002).

Finally, parcels of *la zona agricola* or the agricultural zone constituted the third category of land to be managed on the ejido. From these rich floodplain lands, the agricultural zone parcels produced fruits, vegetables, forage, and fenced pasture. According to those with a memory for the first two decades, the agricultural zone were managed as part of the *colectivo* portfolio for at least the first decade and a half of the ejido's life—that is, beneath the watchful eye of a *mayordomo* and the bureaucrats of the bank and SAHR (personal communication, June 2003). By the late 1970s, however, a de facto private property system had become the norm, with individual parcels managed by individual farmers and householders (personal communication, November 2002). The latter scheme continues to govern the agricultural zone, although now these individual parcels are more or less legally titled and therefore transferable. I will address this situation in the next chapter.

This category of land was intensively farmed. Within the collective system produce at one ejido might be transferred to another for resale or as payment for some other commodity. Four-acre floodplain parcels were allocated by family, but farmed as a unit, with fields often exceeding the size of the individual family allotments. In 1968, 48 acres of the floodplain were planted in apples, taking advantage of the long cool season that is ideal for the tart fruit. Nearby Santa Cruz was famous for its rich apple production, attracting cars and trucks from Southern Sonora, Hermosillo, Caborca, Magdalena, and Nogales. Other crops included cabbage, onions, cilantro, garlic, and lettuce. Besides apples, alfalfa was one of the most important crops cultivated on the floodplain. The *pacas* or bales of alfalfa hay were used to fatten livestock for sale throughout the driest times of the year. Horses, mules and donkeys were often released into these fields to graze the stubble after harvest.

Cattle production

The last four centuries of environmental history of San Lázaro, as well as the rest of northwestern Mexico is inextricably related to a single mode of production-extensive livestock grazing on the deserts and semi-desert grasslands of this large ecoregion. Ask any rural Sonoran and they will tell you that cattle are the lifeblood of this region, both in economic terms and in the imagination, folklore and cowboy (*vaquero*) lifestyle. In the Santa Cruz, young boys (and girls to a lesser extent) will play with makeshift lariats or *reatas*, help care for livestock, and eventually grow into more responsibilities in ranching operations. National holidays, feast days, and other community celebrations will be important occasions for rodeos attended by the entire community as well as neighbors and out of town kin. On such days, teenagers and unmarried young adults will saddle up the best horses and *pasear* or ride around town either seeking or gaining the attention of the opposite sex (see Figure 5.1 below). Local and regional *corridos*, *conjunto*, and *norteño* songs are often filled with *vaquero* themes. And while most families in San Lázaro have few animals nowadays, as I will discuss in Chapter Six, any gathering of men will inevitably generate animated conversations about horses and cattle. This subsection will describe the more recent history of ejido cattle management.

Ejido Miguel Hidalgo was created at a critical time in the history of the regional and national cattle industry. Domestic markets for cattle represented significant factors in the growth of the cattle ranching industry in northwestern Mexico, especially during the post-Second World War boom period when large numbers of people left the Mexican countryside for the urban, industrial labor markets. Between 1954 and 1960, domestic consumption of beef reflected a marked increase of beef in the diet of a burgeoning population. In 1955 Mexico slaughtered over 1.3 million head of cattle valued at nearly 890 million pesos. During that same period, Mexican consumption increased by over 30 percent. Within the same decade, the lands under cattle production increased significantly and shifted in distribution dramatically. In 1950 the national pasturelands of Mexico increased to over 59 million hectares of units larger than 5 hectares, while those smaller than 5 hectares increased from nearly 83,000 hectares to well over 350,000 hectares in 1960. Ejido pastures alone doubled to over 3 million hectares during the same period (Machado 97f, 100). Thus, the smallholder cattle ranchers of Ejido Miguel Hidalgo (San Lázaro) rode in on a wave of growth of ejido-based ranches.

Figure 5.1. Festival day in San Lázaro as out of town visitors and youth *pasear* or ride through town.

Since the creation of the ejido, cattle have been continuously grazing on the collectively or communally controlled pastures (*potreros*) surrounding the ejido's floodplains. Reflecting their greater value to ranchers, horses and burros are kept closer into the community and can be found grazing the pastures of irrigated forage crops along the Santa Cruz River. The semidesert grasslands, oak savannahs and mesquite grasslands have provided good forage for cattle in the community. Carefully maintained fences, sometimes internally demarcated to allow users to move cattle into different pastures and life zones, divide the seven *potreros* themselves. Maintained from 1960 to 1988, collective management meant that livestock management was decided by hand voting in assemblies, consisting of a numerical majority of ejido membership and a leadership commission (*comisariado*). In twice annual round-ups (spring and fall), animals were either moved into new pastures or sold. In many cases, culled beasts were killed and butchered locally, divided among several families until the entire ejido had sufficient protein to last a few months. Sales were organized by officials from the ejido and credit institutions (Banco de Credito Agricola de Noroeste). A large truck would be sent from Agua Prieta to the central corral outside of San Lázaro and cattle were loaded for transport to markets in the United States, while some were sold to buyers from other parts of Northwestern Mexico.

Stocking rates on ejido lands are ostensibly controlled by Article 138 of the Federal Law of Agrarian Reform, which states that ejido assemblies--working with SARH officials--shall determine the ideal stocking rate for communal lands. Members who go over this rate must pay a tax for each animal unit above the limit (Sheridan 1988:93). Although this was rarely enforced, during the first decade of the ejido, older members claim that officials frequently made pronouncements about range health to the *asemblea*, and implied that overstocking limits should be observed. Under the original collective-style management, a heavier bureaucratic hand could be felt which influenced livestock operations. As part of a statewide inventory of Sonoran rangelands, a branch of SARH, known as la Comision Tecnica de Coeficiente de Agostadero (COTECOCA) studied San Lázaro's ranges in 1975 and determined a "grazing coefficient" that would have determined a quantity of head of cattle per hectare. For the ejido, they determined that the agostadero could support an approximate maximum of 4,000 head of cattle including 3,000 calves and 240 bulls on 3,000 hectares of range. As one ejido member put it: "*Aquí nosotros eramos privilegiados, porque si eran terrenos muy cuidados y eso fue una de las cosas buenas que nos dejo el sistema colectivo.*" Here we were privileged because we had well cared for lands and this was one of the best things that collective system left us (personal communication, September 2002).

Cattle production, like all industries in Mexico under the post-Revolutionary *Partido Revolucionario Institucional* (PRI), was controlled through a series of patron-client relationships. In 1936, the government published the *Ley de Asociaciones Ganaderas*, forming three major categories of organization: an *asociación general local*; a *unión regional ganadera* at the state-level; and the *Confederación Nacional Ganadera*. By 1958 there were 1,035 local groupings and 40 regional or state organizations swollen with compulsory membership. The ejido became a member of the *Unión Regional Ganadera de Sonora* (the Association Sonora State Cattle Growers). The Association provides guidance to its members, often complementing education and technological improvement promoted by Sonora's cattle development agency (Fomento Ganadero del Estado de Sonora) and federal programs of the Ministry of Agriculture. Even today, the Association provides genetic improvement programs to ranches such as Ejido Miguel Hidalgo.

Control of Water Resources

Although water—arguably the most important resource for successful agriculture in this arid country--was managed by entire the ejido, it was not excluded from the vagaries of social control. Thirty years ago as well as today agriculture in San Lázaro depended upon supplemental irrigation water, delivered through the *acequia* system of canals. *Acequia* irrigation water is delivered through gravity-fed canals that border and cross the community farmland. The usual configuration is a large canal or *acequia madre* which rings the agricultural land, taking water from a take out point la *toma directa* (or referred to as just "*la toma*") in the stream, and then returning the water into the same water body a few miles downstream. Along the way, each farmer's field or *milpa* is bordered by a lateral or branch ditch that carries the water directly to their crops. The distribution of water through the laterals is determined by a *juez de agua* or water judge, who makes sure that each farmer gets an equitable share of water, contributes to the maintenance of the system, and does not steal from his or her neighbors. Though not necessarily contiguous, the agriculturalists of modern San Lázaro carry on a technological tradition that predates the entry of Spaniards by at least 1000 years. Water from *acequia*-style irrigation takes on new importance, however, in the face of the demands of cattle production in this portion of Sonora.

During the heyday of the ejido period, San Lázaro's agriculture revolved around the needs of rancher-farmers, as it has done for at least three centuries. Beginning in 1960 and continuing to present in some cases, crops raised on the floodplain fields include livestock feed: corn, alfalfa, millet, sorghum, and hay; as well as production for human consumption: beans, cilantro, onions, potatoes, cabbage, garlic, chilies, and lettuce. The growing season for most of the crops begins in October and extends through the spring and sometimes summer, giving farmers ample season for several crops in some cases—if supplemental irrigation water can be supplied during dry periods. In the fall and winter, vegetables such as lettuce, onions, peas, and potatoes were planted, with some forage also planted in late fall, while spring plantings included forage crops such as alfalfa, rye, and sorghum, as well as radishes, cilantro, various cucurbits, chilies, and beans.

More importantly, irrigation water and the technology that controls its distribution are enmeshed in a delicately poised, communal institution that regulates timing and delivery of the resource. Rancher-farmers-called *parciantes* or shareholders-cannot access the water unless they participate in maintenance of the *acequia* system on a regular schedule, or pay a fee to the *juez de agua* for the use of the system-the fee essentially substituting for shareholder labor. Nor can they effectively cultivate their crops without access to that water. In dry years, conflicts often erupted and were mediated by the *juez de agua* but also very often by more experienced *parciantes*. In wet years, the abundance makes the *juez de agua* and *parciantes* easy-going neighbors. The *acequia* management institution hence closely followed the pattern of use and social organization in communities as geologically divergent as the Río Grande Valley of northern New Mexico, Oaxaca, Peru, and Spain (Meyer 1984; Hunt 1989; Gelles 1991; Guillet 1995).

Throughout the community's history, irrigation water in the *acequia* system was supplied by two means: the *toma directa* (direct take) from the stream or the *galeria filtrante* or infiltration gallery. The latter is a sub-surface groundwater collection system, typically shallow in depth, constructed with open-jointed or perforated pipes that discharge collected water into a watertight chamber from which the water is pumped to treatment facilities and into the distribution system. In San Lázaro, the infiltration gallery did not connect to a treatment facility but to a series of settling tanks and then into the main canal for delivering the irrigation water. The infiltration gallery was constructed during the Greene period, but maintained by the ejido until the 1980s when a series of floods destroyed it. In the 1930s, Cananea Cattle Company built the cistern-like system for capturing subterranean river flows just north east of the ranch headquarters.

By the 1970s, however, a series of floods decreased the system's efficiency. In the winter of 1977-78, swollen with heavy rains from a series of Pacific winter fronts, the Santa Cruz River and its ephemeral tributaries overflowed their banks and became a torrent by the time they reached the vicinity of San Lázaro. The Southern Pacific railroad line, running between Cananea and Nogales, Sonora ran parallel to the river at this point, then crossed it just downstream from a series of box canyons (referred to locally as "el Cajon"). The railroad company had constructed a heavy steal and wood bridge at this crossing point. After a quick drop in elevation through confined canyon of el Cajon, the rushing waters, upon encountering the cement footings of the bridge, cut deeply into the banks of the river, undermined the footings and toppled the bridge. They also cut into the intake of the old infiltration gallery, filling it with sand and reducing the flow by a third. The infiltration gallery flow, as discussed earlier, contributed to consistent flows into the ejido's *acequia madre*, and so was a vital component in the irrigation system for the community. Additionally, part of the system's settling tanks that allowed corrosive and potentially constricting suspended sediment to fall out of the irrigation water were destroyed. A second, even more powerful, 1983 flood resulted in the complete destruction of the remaining gallery, intake tubes, settling tanks, and irrigation intake. *Ejidatarios* managed to reconstruct a small impoundment just upstream from the infiltration gallery to capture the meager surface summertime flows, but down cutting and fickle surface flows made a difficult situation worse. In some seasons between 1984 and 2003, fields on the end of the line went fallow for lack of irrigation water. The consequences of these environmental changes will be dealt with in subsequent chapters.

Acequia cleaning generally takes place twice annually depending upon the need for irrigation water and the amount of damage or deposits into the canal system. There is first spring-cleaning before the advent of regular irrigation in March. This involves anywhere from 10 to 20 men (women in this job are unheard of) who follow the *juez de agua* along a section of canal using hoes, shovels, and picks to remove debris from the main channel and in some cases a lateral (though this is usually the domain of the farmer who's plot the lateral services). Related activities include repairing the *toma directa* or headgate of the canal. If floods were bad the winter before, then considerable work might be spent on rebuilding the rock, brush and sandbag diversion that brings water into the *acequia* system. In the fall, depending upon the frequency and intensity of flooding on the Santa Cruz, the *juez de agua* may gather the men together for a second cleaning and repairs if necessary, though resistance to this cleaning is usually greater because monsoon moisture has increased soil moisture and the farmers are often occupied with more livestock-related activities at that time. It is interesting to note that *acequia* maintenance and application follows the same annual pattern, technology, organization, as in the markedly different environment of northern New Mexico but the Sonorans use different terminology to describe their system (cf. Crawford 1988; Meyer 1984; Rivera 1998).

Summary: the Ejido Collective Period and the Adaptive Cycle

Post-Revolutionary Mexican governments used the 'social sector' or ejidos like Miguel Hidalgo to solidify their stranglehold on the countryside and all but guarantee that the most powerful party, the PRI would govern the nation for 71 years. Through a highly bureaucratic system of top-down structures incorporating rural finance, community organization, marketing of agricultural products, and services like healthcare or education, the federal and state governments from the 1930s to the 1990s controlled the activities of the ejido, leaving little agency at the local level. In their attempts to create a model agrarian utopia, Mexican governments from the 1930s to the 1980s also placated peasant unrest, and promulgated rural development policies that served to cultivate markets for cheap food to feed urban growth. The social sector was also a place for social experimentation, some of which could be found in Ejido Miguel Hidalgo and the rest of its cohort communities in the San Pedro Watershed. The *colectivo* style of management is the primary example.

At the same time, the organization of Ejido Miguel Hidalgo and other arid land communities was ideal for the management of natural resources such as common pool rangelands and irrigation systems. Although floodplain farming was perhaps best adapted to household-level, individualized intensity (cf. Netting 1993; Sheridan 1988), the collectivized organization of these two other elements of rural livelihoods in San Lázaro managed to spread economic and environmental risk among a larger population of households. This is especially true in light of the environmental variability of both rangeland and water resources. Obviously, though the ejido did not have much time to adapt this form of management to best fit all variability. On more than one occasion, nature—who always bats last as the bumper sticker goes—sent one out of the ball-park in the form of a major flood or drought period. These were typified by the flooding that occurred in the mid-1970s and early 1980s, destroying the ejido's technological (and hence financial) capital, and by reducing its ability to respond appropriately to drought that occurred later in the 1990s and continues into the present. In fact, the most intense transformations of the social-ecological system (SES) during the history of the modern ejido can be traced to catastrophic environmental changes coupled with higher-level policy signals that reduce innovation and adaptation at the local-level.

Yet overall and perhaps by serendipity rather than strategic design of the Mexican government, the collective system allowed for more ecological or social resilience in the face of variable watershed conditions for rancher-farmers than the period I will describe next. For example, cattle were moved from pastures to ranges depending upon the condition of forage and the needs of the collective for economic gain. Marketing beef or calves were done as a group, rather than by pitting individuals against multiple buyers. Water works—the *acequia* system especially—were managed to equitably share the maintenance costs and benefits across all users in the agricultural zone (which were also, in theory, equitably distributed). The system of *asemblea* meetings built social capital at the same time that it ostensibly controlled the ability for any community member or group to control particular resources. Collective action with regards to water, range, and farmland resources was initially an innovative institutional strategy that allowed social learning and response to changing common pool resource availability (or natural capital).

On the other hand, while the ejido was largely formed of locals who may have been able to demonstrate enough knowledge of the local conditions to manage the range and river system within appropriate environmental constraints, the ejido was plagued by the state's meddling or usurpation in lower-level resource decisions (Rappaport 1994: 273f). While local knowledge evidenced increasing levels of cultural capital at the local level, decision-making was quite often dependent upon signals from outside of the ejido. This—for good or ill—forced ejido members to make decisions that did not jibe with what was best for their own economic or environmental situation. Furthermore, while the ethnographic evidence is largely indirect and anecdotal, the state and its bureaucratic armature engaged in corrupt activities that reduced the community's natural and economic capital while restricting its agency. The ejido's stocking rates, for example were set by bureaucrats in the Ministry of Agriculture and Water Resources, not by decisions of the ejido *asemblea*. In discussions I had with ranchers active in this era, the *ejidatarios* implied that the ministry's technical representatives from COTECOCA were setting the stocking rates much higher than would be appropriate and that someone was profiting from the difference and it wasn't the ejido (personal communications, July 2002 and November 2002). These data evidenced a trend towards greater control by K-strategists from higher in the multi-scalar hierarchy that typified Mexican society.

More importantly, we can see that from its inception, land use decisions at the ejido level were controlled by a host of political actors ranging from the PRI and its clientalist associations down to individual bank officials in Cananea and Hermosillo. The scale of the land-use decision making was mediated by institutional factors such as markets and policies rather than by changes on the ground and within the economic context of the community or its households alone. Extreme biophysical events—the flooding in 1978 and 1983—led to changes that needed immediate, on-the-ground decisions, primarily in the form of economic resources to repair the damaged infiltration gallery. Yet the tightly linked higher levels of the ejido's institutional framework were not able to respond appropriately and, in fact, it did not respond at all. The frustration that ejido members expressed about this and other moments of perceived malfeasance continues to be palpable in 2006, and probably helped drive the ejido to take the steps it did to break with the government's top-down management in the 1980s and 1990s.

Like other multi-scalar SESs in Mexico, economic signals were not consistent with either local environmental conditions or the needs for stable livelihoods. Instead, easily accessible yet expensive credit bolstered a cash-dependent economy. The costs of credit again proved to reduce households or individuals' abilities to maneuver appropriately across the uneven economic landscape. Overall, the community was consistently undercapitalized and over extended by debts. If prices for agricultural products—primarily beef—dropped with currency fluctuations, or input costs increased with national adjustments, ranching families were forced to convert credit destined to bolster production into cash for household expenses. To repay these debts, the households were forced to make decisions that undercut their long-term viability (such as selling off calves at less than favorable prices).

As the end of the 20^{th} century neared, however, the state level interference took on a new more negligent character. These new relationships generated a whole host of problems for the community, especially when coupled with environmental consequences that are felt most acutely in San Lázaro, and not in the Federal District of Mexico. During its first three decades of existence, the SES of Ejido Miguel Hidalgo went from a period of innovation and growth (α- and r-phases) and then fell victim to its success as K-strategists took advantage of opportunities to control its resources, suppressing innovation. If innovation is suppressed, a system may become unable to reorder itself into a new structure. Impoverishment and disorder then persisted and intensified during the 1980s, resulting in the need for outside interventions—which were not forthcoming. By the advent of the neoliberal experiment of the 1990s, the community was prepared to tear apart its structures in a fit of Ω-phase creative destruction. This Ω-phase is the subject of the next chapter.

CHAPTER SIX: EJIDO POST-MORTEM 1991-2003

The households of Ejido Miguel Hidalgo and San Lázaro endured a three decade-long period that began with the rise as a frontier agricultural town carved out of capitalist holdings and has evolved into more marginalized community where agricultural development appears to have stopped and where other livelihood strategies have come into greater play. This chapter describes this community-level transformation and illustrates the confluence of unfortunate political-economic and environmental variables that have spelled the doom for Mexican agriculture across much of the arid northwestern Mexico. Lambin et al. (2001: 266f) concluded that economic conditions have been the predominant factor that control individual and social responses. Although conditions are context specific, land use change is mediated by institutional factors such as markets and policies. In the case study of northwestern Mexico, those factors include a history of federal governmental mismanagement followed by more recent wholesale abandonment of small-scale, communal agriculture; the redistribution of land and water resources through restructuring of tenure arrangements; and the development of new economic opportunities for households in non-agricultural livelihoods.

As I have asserted from the beginning of this study, institutional factors alone cannot explain the pace of change in San Lázaro, or elsewhere in political ecology. While institutions are the strong, even dominant signals with regards to economic decision making, environmental signals are also in play with significant results. In the case of northwestern

Mexico, this includes most prominently a dramatic shift in climatic as well as hydrologic regimes leading to a general desiccation of agropastoral ecological resources. Land-use has subsequently changed. The latter set of ecological changes has become a sort of death of a thousand cuts that has reduced the community's ability to tap local natural capital and thereby generate economic capital. This chapter highlights how these variables have played out in the creation of the ejido's circumstances and resulting strategies for success. The impact of these changes is most visible in the ways that ejido's residents have sought to distribute economic and environmental risk.

Neoliberalism and Agriculture in Mexico

The economic and political signals that were received and processed into land-use decisions in northwestern Mexico and San Lázaro had been highly inconsistent and difficult to interpret from 1960 to 1980. Mexico combined statist policies that generated wealth through nationalized oil markets, patron-clientalist bureaucracies that sought to mobilize control for political ends, and accumulated massive amounts of debt by deficit spending to placate the poor and elite interests simultaneously. But by the late 1970s, the political economy of the nation verged on a collapse into economic (and therefore political) anarchy. Oil shocks had sent the Mexican peso into over inflated territory and interest rates soared into the economic stratosphere in an effort to control inflation that had already engulfed the United States' economy. As Mexican's are fond of explaining "when the U.S. catches a cold, we catch pneumonia!" At the same time as this storm was brewing, bankers, economists, and policymakers in Washington were forming an ideological consensus that would be tested in Mexico. The neoliberal experiment would form a serious and consistent set of signals for local interpretation into new forms of land tenure and land-use in San Lázaro and the Upper Santa Cruz Watershed. These new interpretations would then translate into consequences for ecological resiliency in the community and its watershed context, especially when tested by multi-scalar ecological factors.

From the 1950s to the 1980s, Mexico's industrialization was coupled with policies to encourage agro-exports rather than production for domestic markets. Under these policies state support was directed mainly toward medium and large-scale producers who could capitalize on Green Revolution technologies and easily monitored credits issued by nationalized banks (Wright 1990). However, Green Revolution technologies proved fickle and results tepid so state investment and capitalization of industry began to overtake those in the agricultural sector. Smallholders in the social sector were dissimilarly encouraged to produce for domestic and highly localized markets. Nationally, the social sector was consistently under-capitalized. Furthermore, ejidos and their ilk were concentrated in areas less favorable for commercially viable agriculture, and so never produced enough for domestic markets. Basic staples production lagged and was eventually subsidized in the 1980s by subsidization programs such as Compañía Nacional de Subsistencias Populares (CONASUPO). By the 1970s, all sectors of agriculture were receiving a declining share of investment and subsidization.

Instead of shoring up domestic production, successive federal governments saw the short-term financial efficacy of replacing agricultural investment with industrial investment that would encourage urban industrial development as a replacement for rural "excess labor" (Rostow 1960). Growth was concentrated in a few regions of the country--the industrial heartland of the capital and the border cities--and in one or two manufacturing industries. From 1970 to 1990, the total gross domestic product attributed to Mexican agriculture produced dropped from 20 to 11 percent; while industrial production grew from 20 to 34 percent during the same period. At the end of this two decade period, the industrial sector amounted to over 60 percent of Mexico's economic output while agriculture languished (Adams 1997: 14).

By the 1970s, Mexico had progressed through a series of unsustainable growth spurts followed by forced currency deflations and recessions. The Mexican state had sought to promote modernization in alliance with the Mexican business elite by refraining from taking actions that limited private sector profitability. The nation's leaders never developed a strategy to deal with the country's worsening balance of payments situation or to sustainably fund its social programs by raising taxes on elite profits. Industrial production was increasingly directed towards the protected domestic market while the largest players remained heavily dependent on foreign technology, capital, and inputs. Moreover, the largely ignored agricultural sector was unable to generate the foreign exchange needed to cover the growing imports of consumer durables and capital goods.

As a partial solution, President Luis Echeverria (1970-1976) tied the nation's accounts to oil revenues coming from the southern half of the nation and opportunistically applied these futures to the impending worldwide oil crisis that would--in theory--bring price inflation. At the same time, recession and inflation vexed the U.S. economy such that it sought to control a downward slide of the U.S. dollar; the government forced up global interest rates and caused worldwide economic downturn. But the discovery of vast oil reserves in Tampico buoyed the Mexican economic miracle and the spendthrift height of President Lopez Portillo's (1976-1982) administration. Lopez Portillo continued and expanded Echeverria's profligate deficit spending. In 1980, the party ended when a glut on the market and an ill-conceived market bluff by Lopez Portillo caused oil prices to plunge rapidly, taking the last wind from Mexico's remaining export revenue stream. The bottom fell out of the miracle, and left the administration of Lopez Portillo little choice but to devalue the Mexican peso by 78 percent in 1982. Seven months later, the Mexican government suspended payments on its national debt. This was followed by a second, 60 percent peso devaluation. With serious capital flight threatening the basic stability of the nation, Lopez Portillo then nationalized the banks. The strategy backfired and led to more flight by investors. The final straw left Lopez Portillo's successor—Harvard educated Miguel de la Madrid Hurtado with little choice but to turn to the U.S. government for help (Hart-Landsberg 2002).

The economic collapse and crisis of the early 1980s led successive Mexican governments, starting with de la Madrid, to buy wholeheartedly into an emerging neoliberal experiment. Neoliberals in the Reagan administration and elsewhere saw in a virtually bankrupted Mexico and the U.S.-trained technocratic regime of economist de la Madrid the opportunity to pilot their new policies (Harvey 2005: 41, 73f). A product of the so-called "Washington Consensus," the structural adjustment program (or SAP) was conceived as a means to force U.S. direct investment into new, developing country markets (Greenberg 1997: 85f). Mexico became the first nation to undertake the level of economic adjustment involved; lessons learned there would pave the way for dozens more SAPs implemented throughout the developing world. The U.S. government, taking advantage of Mexico's request for financial assistance, demanded that the Mexican government reduce its domestic spending, privatize state firms (starting with the newly nationalized banks), and open domestic markets to foreign trade and investment (Harvey 2005: 94f).

Technocratic President de la Madrid ushered in a period of adjustment that would send Mexico into devastating economic recession three times over his term. He slashed government spending in a number of areas including programs aimed at smallholder and social sector agriculture. The de la Madrid administration also cut parastatal investment. In 1984, the state controlled 1,212 firms and entities. The number had been reduced to 448 by December 1988 (Hart-Landsberg 2002; Harvey 2005: 101). The privatization of state-run businesses was not just an issue for urban industry. For the agricultural sector, this meant that chemical input and drug manufacturers (for livestock vaccines), as well as food processing companies shifted ownership. Price hikes followed. This spelled the beginning of the end for both subsidized inputs and more stable farmgate prices that had been a major support for ejidos like Miguel Hidalgo.

The peso did not stabilize until the first year of the administration of President de la Madrid, when the IMF austerity program was put into place. De la Madrid brought in a new era for Mexico--the era of the technocrat in which new economic policies focused on integrating the nation into the world market. Under de la Madrid, Mexico would become the rising star of the new "emerging markets." Although de la Madrid brought inflation down and laid the groundwork for Salinas de Gortari's successes in the latter half of the decade real wages fell by nearly 50 percent during the 1980s, and did not show any recovery until 1989.

La reforma agraria: Agrarian Reform

During the subsequent term of President Carlos Salinas de Gortari (1988-1994) the relatively blunt tools of neoliberal structural adjustment penetrated ever more deeply into rural Mexican political economy. He continued to privatize parastatal companies upon which both urban and rural Mexican depended (including the state telecommunications monopoly, chemical and steel industries). From 1989-1994, over $91 billion in foreign capital flowed into Mexico to purchase these and other investments (Harvey 2005: 94). Along with real investments, international currency traders perceiving a good buy in Mexican bonds and currency also temporarily buoyed the economy. As the new peso increased in value, imports became steadily more expensive for the average Mexican—including agriculturalists along the U.S.-Mexican border where many inputs came from nearby U.S. sources.

Most importantly, the Salinas de Gortari administration began new and politically difficult negotiations to end the Mexican agrarian reform program begun in the post Revolutionary period of the 1930s. Armed with the vision of transforming the social sector of ejidos into individualistic Jeffersonian yeoman agriculturalists, the Salinas government and its allies in the Distrito Federal, rewrote Article 27 of the Mexican Constitution.

This rewrite did several things that were critical for *ejidatarios* throughout Mexico. First and foremost, agrarian reform--the expropriation of lands from large land holdings was formally ended. The second major change was that ejido members could now sell, buy, rent or lease their lands, activities forbidden under the original *Ley Agaria*. *Ejidatarios* could also form partnerships with private enterprises or investors. Private credit could be secured using privately titled or even communally certified lands as collateral (Cornelius and Myhre 1998: 2ff).

A new program called the *Programa de Certificacion de Derechos Ejidales y Titulacion de Solares Urbanos*, or Program for the Certification of Ejidal Land Rights and the Titling of Urban House Pots (PROCEDE) was introduced, with the goal of measuring and registering all newly formed individual ejido plots. The bureaucracy of PROCEDE was charged with overseeing the transformation of ejido lands into private land ownership or *pleno dominio* as well as issuing, mapping and titling certificates that acknowledge land use rights to ejido common lands. It was the later process that formally titled the six range management groups in San Lázaro's modern land tenure scheme (see below). Beneath the umbrella of the supervisory Attorney General's Office for Agrarian Affairs, or Procuraduría Agraria (PA), PROCEDE was joined by host of other related programs such as the national agrarian registry (RAN), a new ejido mapping division of INEGI and an agrarian tribunal for settling disputes (Nuijten 2003: 479).

Of the many significant aspects of the newly rewritten constitution, the retitling process had one of the most immediate impacts on the community. Three officials from PROCEDE visited Ejido Miguel Hidalgo in late fall of 1992, not long after the agency was formed. In the name of efficiency, the PROCEDE representatives combined their meeting with ejidos in neighboring Cuitaca and Santa Cruz. The three ejidos were offered maps for their newly privatized plots, official certificates for communally held lands, and coveted titles for their *pleno dominio*. The officials made two return trips to the subsequent year, providing some copies of maps from their original declaration paperwork (formally creating the ejidos), but for the most part left the ejidos to their own devices. Since members of Ejido Miguel Hidalgo had already divided their communal rangelands into separately managed pastures in 1989-1990, they were only asked to provide hand-drawn maps of the boundaries in exchange for the titles. The National Institute of Statistics and Geography (INEGI) never confirmed or surveyed these boundaries, though according to the ejido president at that time, most ejido members considered the maps to be sufficient to prevent incursions and conflicts (personal communication, March 2003). On the floodplain, the parcels that had been collectively managed until 1988 had already become subject of a small but lively land market. Rights (*derechos*) were traded freely among *ejidatarios* or when outsiders approached with offers of cash payments. Yet, as the *juez de agua* commented, without regularly available irrigation water in the *acequia madre*, most *ejidatarios* were uninterested in investing in the plots (personal communication, July 2002). In 1994, a businessman from Hermosillo approached a group of ejido members and purchased the rights to over 15 hectares of floodplain near the *rancho* (satellite community) of Agua Zarca (personal communication, February 2002). The water provided to his 4 hectares of cultivated seasonal vegetable fields is pumped illegally from the shallow Holocene alluvium along the Santa Cruz--though no one in the community has ever contested the taking of community water since it was far downstream from most remaining farming operations and the town's water supply well.

In many respects, the retitling process of PROCEDE went remarkably smoothly in Ejido Miguel, San Lázaro. *Ejidatarios* claimed that at the time, the community "*deseamos un nuevo comienzo y nunca peleamos por causa de tierra ni nada*," we wanted a new start and we never fought over land or anything (personal communication, July 2003). More importantly than just cooperative attitudes, the ejido was relatively young when compared to some communities in Mexico where long-simmering land conflicts have dominated. Furthermore, Ejido Miguel Hidalgo had been managed as a *colectivo* until the early 1990s, meaning that an individual member's cattle were mixed into large herds that were then stocked in communally operated ranges. Agricultural land on the floodplain was individually parceled, but according to active farmers, without ready water beginning in the mid-1980s, no one raised objections to boundaries, except when sales became official after 1993 (personal communication, December 2002). *Ejidatarios* saw this transformation from collectively managed to individually held lands as a huge windfall, since they could then sell their lands in the new privatized environment.

The most significant outcome of the PROCEDE certification process was the ability for *ejidatarios* and potential *ejidatarios* to trade lands formally and legally. The *asemblea ejidal*, or highest internal decision making body is empowered to approve changes in tenure that were legally impossible prior to 1992, including sanctioning sale or lease of an *ejidatario*'s rights (*derecho*) to lands. The new *Ley Agaria* stipulates that any given *ejidatario* may present their case to the *asemblea,* given that PROCEDE has certified the ejido ready for sales, and have their arrangements approved by a simple majority vote (Mexico 1992: 21). Between 1992 and 2003, 26 out of 104 *ejidatarios* sold rights to their lands to outsiders (Martínez Rodríguez 2000: 22). According to a past ejido president, most of those outside purchasers have come from neighboring Santa Cruz (personal communication, June 2003). Along the entire Mexican reach of the upper Santa Cruz River, most of the ejidos have legally restructured through the PROCEDE certification process and have significantly altered land tenure (see Table 6.1 below). The greatest changes are seen in the relatively impoverished communities closer to Nogales, Sonora. Interviews with two ejido leaders here revealed that a majority of urbanites have established second homes and farms, replacing the original tenants who left the less productive landscape behind years ago (personal communication, June 2002).

Table 6.1. Changes in ejido land ownership, Upper Santa Cruz Watershed.

Ejido	**Original membership**	**Actual membership**	**Memberships sold after 1992**	**Δ%***
Miguel Hidalgo	142	104	26	25
Santa Cruz	200	114	22	19
Álvaro Obregón	25	18	5	27
Centauro de la Frontera	27	39	15	38
Adolfo López Mateos	84	53	6	11
Miguel Cárdenas Valdez	96	51	11	21
Mascareñas	52	18	6	33

* Percent change between actual membership and post-1992 land sales.
Sources: Martínez Rodríguez 2000:22, augmented by field data gathered, 2002-2004.

La crisis and Monetary Policy

The technocratic administration of President Carlos Salinas de Gortari accompanied its neoliberal policy of privatization with a laissez faire monetary policy that greatly impacted agriculturalists such as those in San Lázaro, principally by leading to a serious economic and political crisis that gripped most of Mexico for much of the mid-1990s. Beginning in the early 1990s, the Salinas administration first introduced new currency that would be tied to the dollar, and due to a handy shift in decimal places, moved the peso from 3,270 pesos to a dollar (in 1993), to a convenient 3.27 to a dollar (Wheat, 1995). Secondly, rather than encourage investment in working capital, equipment and hard investments, Salinas and his administration worked hard to woo foreign (mostly US-based) portfolio investors back into Mexico, despite the nation's long history of dubious financial stability--especially during the multiple crises of the 1980s. In 1994, interest rates as high as 18 percent on Mexican *cetes* and *tesabonos* attracted billions in electronic transactions to flow through Mexico City (Wheat, 1995). Foreign investors rushed to invest in what was perceived as a hot market. The

Mexican stock market was pushed to bullish new heights.

Meanwhile, Salinas and his administration had greater plans based on the seemingly endless success of the market. Salinas and the PRI used the strong peso, the flood of investment, and the promise of a NAFTA-driven prosperity to court the middle class and urban workers of Mexico for the upcoming 1994 elections (Lindau 1996). Across the border and in a similar vein, the Clinton administration used the "Mexican miracle" to peddle the NAFTA and eventually the Uruguay round of GATT to skeptical voters and a skeptical Congress (Wheat 1995). The marriage of the North American economies seemed eminent by August of 1993.

The Zapatista uprising on January 1, 1994 brought the Mexican neoliberals' honeymoon to a quick end. The uprising inspired millions of Mexico's rural and urban underclass to speak up, and by late spring, protests in front of the National Palace had become a constant reminder that the technocrats had overlooked some political details among their economic indicators. The rebels in Chiapas were immediately successful in using the media to focus worldwide attention on the persistent neglect or malicious repression of Mexico's poor and indigenous populations (Collier 1994: 16). The political assassination of PRI candidate Luís Donaldo Colosio in February and later the gunning down of PRI Secretary General Jose Francisco Ruiz Massieu led to lengthy and cynical debates in much of Mexican society about the efficacy of their single-party dominated government (Lindau 1996). The bad press spread from the assassins to Salinas' own family and cabinet. Disgusted murmurs became even more persistent and brought some middle class support to the protests in the Districto Federal. By the summer of 1994, the much-touted "Mexican Miracle" began to look more like bad dream.

By mid-1994, investor jitters had produced new survival strategies in the Mexican stock market. Where previous investment had been diverse, now investors demanded short-maturity, dollar-denominated *tesabonos* (federal bonds) and rapidly dumped the longer-maturity, peso-denominated *cetes*. Mexican *tesabonos* went from less than $5 billion of the total of foreign held bonds, to well over 10 times that value by December of 1994 (Wheat 1995). The debt rolled over weekly and the Mexican treasury was faced with less foreign currency to service its massive domestic debt. With the foreign money transformed from a flood to a trickle, Salinas had a choice to either devaluate or to hike up interest rates (Gil-Diaz and Agustin Carstens 1996).

Instead of either unwelcome choice, Salinas's government began using its $30 billion in foreign-currency reserves to buy up pesos, at times spending $1 billion a day. Then-President-elect Ernesto Zedillo asked Salinas in October to let the peso fall-- a request Salinas is said to have flatly rejected (Levinson 1995: 52). By December 19, reserves were below $10 billion and falling fast. Zedillo had no choice but to abandon the pretense that 3.5 pesos were worth a dollar. The peso tumbled by 70 percent before climbing back to five to a dollar in January. Markets from Washington to Buenos Aires and New Deli shuddered with Mexico's fall from grace. Economist Rogelio Ramirez asserted that, "Zedillo inherited a situation that required surgical care, but he performed the operation like a veterinarian" (Levinson 1995: 53).

Like the legalization of land sales and leasing, the economic crisis of the mid-1990s served as a stimulus as well. In San Lázaro and elsewhere in Sonora, *campesinos* felt the sting in skyrocketing interest rates, forcing some to sell off assets to pay down debts, or make a stand with the *Barzon* (debtors) movement. No one in San Lázaro was forced to take such a stand, though some I interviewed mentioned family members in Hermosillo, Cananea, and Nogales attending protests (personal communications, December 2002; July 2003).

The most significant impact, however was that farmgate prices suddenly plunged while input costs—many of which were of foreign origin were priced out of reach. More importantly, credit became excessively expensive--up to 87percent for private credit while the Mexican prime rate topped 69 percent. Because of the sudden devaluation, the peso could only buy a fraction of what it had been able to do prior to 1994 for those crossing the border to purchase household and farm inputs--one of the advantages for borderland agropastoralists. With inputs more expensive, those who maintained farming operations on the floodplain began to divest themselves of it, either through leasing arrangements or by selling the land itself. Examination of ejido records for this period by the author and former ejido comisariado revealed that during the period of 1994-1998, 38% of ejido members who had maintained title to farmlands established leasing arrangements of all or part of their holdings. As I will describe below, at only 12 out of 142 households still cultivate their holdings on the floodplain. The *juez de campo* (cattle boss) during the years of the crisis also explained that price of vaccinations (many manufactured in the United States for the Mexican market), new breeding stock, and tack related to cattle production were also impacted (personal communication, June 2003). Furthermore, as the reader will note in Figure 6.2 (below), the price of feeder calves in the United States plummeted to record lows in 1995 and 1996. Therefore, regardless of the domestic market's instability, the export market for the primary commodity in the region was also exceptionally bad.

The Fulcrum of Change: Ejido Reorganization, Tenure, and Management

The local implications of these macro-scale political economic changes were multifaceted. First, in response to both internal (disgust with the bank-driven system of management) and external (legalized retitling and land markets) stimulation, the ejido modified its system of organization, governing the management of its resources--namely the scarce bottomland, water, and the abundant but variable rangeland. With the reorganization came drastic changes that transformed tenure to quasi-individual[11] from collective ownership. With these changes in management and tenure came shifts in who maintained ownership of ejido lands, perceptions of ejido community, and ultimately, environmental consequences resulting from new norms, patterns of land use and livelihood strategies. This section will deal with the first two processes, while the subsequent section will address the consequences.

Like a great agrarian and social experiment that it is, the Mexican ejido system of organization has been subjected to many changes in governmental vision over the last 70 years. The ejido has been alternately reviled and undermined, or used as a necessary foil for neglecting rural Mexico, or used to bolster urban, industrial development strategies. And always, the government's attention to the ejidos or "social sector" has been closely tied to the politics of keeping the dominant party in power. Until the technocratic, neoliberal revolution of the 1980s, Ejido Miguel Hidalgo, however, has been an exception, experiencing a relatively stable management regime. This may be because changes in individual ejido organization were less important to the last 40 years of governments than control over the financial institutions and larger organizations responsible for ejido decision-making--namely the *Sociedad Ejidal Colectiva de Cananea*.

From 1960-1990, Ejido Miguel Hidalgo was organized as a *sistema de uso colectivo* (system of collective use). Members of the ejido (*socios*) worked the land, cattle, and water through group decision making, democratic institutions, and a series of elected community leaders, each organizing divisions beneath them. These divisions supported the various operations important to the community's collective livelihood. Principal among these was the *juez de campo* (cattle boss), the separate *ranchos* or satellite communities. Another central duty—handled by the *juez de agua* (water judge)—revolved around domestic water provision to the community, water provision to the farm fields and the various cattle tanks around the landscape. *Mayordomo*s (bosses) were placed in charge of housing and urban infrastructure, vehicle maintenance, and agriculture on the floodplains of the Santa Cruz River. These *mayordomo*s reported directly to the *asemblea ejidal* and the *presidente ejidal* (ejido president). Regular meetings of the *asemblea* allowed each *mayordomo* or *juez* to report on the status of

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[11] I use the term "quasi-individual" because after the PROCEDE process, the ejido's rangelands were still

their duties. New *mayordomo*s or *juezes* could be appointed by the ejido president and with consent of the *asemblea* if a particular member asked to step down from their duties. If a *mayordomo* appointment was opposed by a sufficient number of ejido members, they could take their protest to the *presidente ejidal* and ask for another boss to be appointed instead. But with tight social relationships the norm in the community, these types of problems were rare to non-existent. Leaders all knew each other and if people were dissatisfied with a particular *mayordomo*, conflicts were settled swiftly.

These division bosses were important links in the relationship between ejido members and the community as a whole. They brokered deals for more funding, labor or other resources as the ejido set its budget each year in under close guidance of representatives from the Banco Ejidal, based in Cananea. *Mayordomo*s and *juezes* were also responsible for conflict resolution within each division. This was especially important with regards to water provision and the maintenance of the *acequia* that irrigated the floodplain fields. Their careful management was also critical to maintaining equitable distribution of resources such as labor for cattle drives, harvests, and vital urban infrastructure.

This system stood for the nearly first three decades of Ejido Miguel Hidalgo. In 1990, the *colectivo* structure was abandoned, with the exception of the ejido president, the cattle boss and the *juez de agua*. Monthly meetings of the ejido *asemblea* were abandoned in favor of annual affair. A voluntary ejido council now controls community-level decision-making. The council meets sporadically; usually only when necessary. The election of

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communally organized within *grupos de manejo*, while farmlands on the floodplain are truly wholely owned, president is no longer a process for all of the ejido households to participate in, but is now largely ceremonial and decided among the members of the ejido council and other interested parties.

While the colectivo structure governed the management of the ejido's resources for two decades, *asembleas ejidal* or ejido assemblies brought the membership of the ejido into more active and open decision-making. *Asembleas ordinarios* of at least 51percent of the ejido membership were held on the first Sunday of each month. Ejido members joined the *comisario* (council) made up of the president, secretary, *consejo de vigilancia* (sergeant at arms or sheriff), and treasurer. The *comisario* could also convene extraordinary meetings (*asembleas extraordinarios*) when government officials came to town or when an ejido member was selling the rights to their share (and thereby leaving the ejido). According to the last ejido president, *asembleas* have become infrequent in the last decade, more or less restricted to extraordinary occasions of ejido share sales or important visitors (personal communication, August 2002).

The *asemblea* was the primary vehicle for transparent financial and resource management decision-making by ejido members. *Asemblea* participants would gain information on ejido funding, and were frequently attended by 2-3 Banco Ejidal representatives. *Socios* could also present to the *asemblea* and its leadership their credit needs or payment plans, ostensibly removing a potential source of corruption or exploitation. Importantly, ejido *asembleas* were places for programming resource uses such as livestock

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although water rights are still socially distributed.

sales, agricultural zone management, installing new wells, and *acequia* cleaning. Members could vote for whether an activity should proceed although a former leader revealed that few conflicts occurred in these meetings and most projects were voted for unanimously (personal communication, August 2002). *Reforma Agraria*--the agrarian reform agency with primary responsibility for dispersing and administering lands to the social sector--also sent representatives to these meetings, sometimes accompanied by SARH officials. With the 1992 passage of legislation reforming Article 27 of the Mexican Constitution, these mandatory, monthly *asembleas* were no longer legally required. While this new letter of law freed the community from the monthly obligation, the economic and organizational impetus that drove the meetings themselves changed radically in the early 1990s.

<u>New Roles, Management and Collective Organization</u>

Other significant changes in the system of organization took place in recent decades. In 1990, with encouragement of *Reforma Agraria* and SARH (at that point renamed SAGARP by then president Carlos Salinas de Gortari), the ejido formed 6 *grupos comunales* (communal groups) composed of 23-26 individuals that governed the use of the pastures in the ejido. As a former ejido leader explained: "when we made the groups--they [the ejido members in each group] started meeting regularly and lost interest in the *asembleas*. Most of the questions dealt with in the *asembleas* were economic and now the groups dealt with them" (personal communication, June 2003). It was at this point that Ejido Miguel Hidalgo's system of organization began a two year transformation from the *colectivo* or collective system where resources--especially land--were managed by the entire membership through *mayordomos* or *juezes*, to a communal use system (*sistema de uso comun*) in which resources are controlled through each group--though individuals are encouraged to make their own decisions about what animals to sell, when and for what price. This last fact is perhaps the most pivotal change in the ejido's history since it's formation in 1959, as I will discuss in greater detail below.

Among the older members of the ejido--those of span the period from the 1950s to the early 21st century, perceptions of the ejido's organizational evolution are important. As one old timer put it, "we were united by our economic interest under the collective system. Back in those days, we were purely *ejidatarios*. We weren't open for outsiders to purchase land in the ejido. Now we have lots of outsiders and children who of *ejidatarios* who are not members." Still, this same *ejidatario* responded that the change was "*por lo mejor*" for the best. The current ejido president, served as an important leader for several periods in the ejido's history. He too echoed the same sentiments, as did several other former *comisariado* members. Another former division boss referred to the collective period as "*comunista*" (communist) and stated that being able to apply for your own credit and make your own decisions was much better for everyone.

While the transformation from collective to a combination of communal management and individual tenure was revolutionary, it didn't happen overnight. More importantly, the ejido was not a passive part of this change but maintained agency that is often overlooked in academic discussions of neoliberalism in Mexico. Mexico's conversion from statist to neoliberal vision was already underway in the late 1980s under President Miguel de la Madrid and his successor—Carlos Salinas de Gortari. Regarding the reasons for the change, Ventura responded that, "*Nosotros nos preguntabamos porque en otras partes habian ejidos individuales, porque a nosotros nos tenian detenidos con un regimen que nos estaban administrando de fuera, siempre los comisariados que entraban no eran ellos los que administraban, siempre era gente del banco, eran los que venian a dar a conocer los deudos, creditos, por eso nunca hubo una persona capacitada para eso*." We asked ourselves why there were individually controlled ejidos in other parts [of the country]. Because they had us locked within a regime that was always controlling us from outside, always it was the *comisariados* who administered, always with people from the bank, these were the ones who knew about our debts, our credits. There was never any person here with the skills to deal with these issues (personal communication, September 2002). *Ejidatarios* of Miguel Hidalgo felt that the previous system left them significantly less empowered to govern their own economic affairs--especially the most sensitive issue of credit.

Under the new system, *ejidatarios* could apply for their own credit, but also had to take responsibility for a variety of things that were handled by the group prior to the change in organization and tenure. For those who continued cattle ranching, *ejidatarios* now sell their animals on an individual level to cattle buyers from surrounding communities (or even as far as Sinaloa), rather than the prior system where the ejido collectively sold stock biannually through a single broker-buyer who was contracted by the *comisario ejidal*--although this buyer was generally always suggested by the Banco Ejidal.

More importantly, the *ejidatarios* consistently express that the system was subsuming their economic and social needs to the greater good, but that this wasn't always in synch with their own perceptions of what was best for their households and community. The change has been more than an economic alteration—it has generated feelings of liberation and autonomy. Furthermore, the new tenure system was sought after by the *ejidatarios*, rather than simply imposed from faceless bureaucrats. An important element of agency remains with the community itself.

The changes wrought by the administration of Salinas de Gortari ended a rock solid institution of agrarian reform that began in the tumultuous years following the Revolution. Although the ejido was designed to placate peasant desire for lands, at the same time it also formalized a patron-clientalistic relationship between the Mexican State and agrarian communities. By the late 1980s, the sentiment among both Mexico City technocrats and *campesinista* reformers was that their structure did not suit either the demands of the modern, increasingly globalized agricultural economy, or the needs of peasant communities within them. Without access to sufficient credit and capital investment, the social sector was languishing in a subsistence mode of production, with off-farm labor providing cash while a few basic staples were produced in small quantities. In response to the drying up of the credit market, *ejidatarios* sought or were sought out by investors who clandestinely leased their parcels, in order to amass sufficient land to reach economies of scale suitable for viable cash crop production. *Ejidatarios* were often at a disadvantage in these deals, and many times found themselves working on the larger farms that constituted their formerly individual parcels. Technocrats and their *campesinista* allies rationalized that legally privatizing these tenure relationships might shine light on bad practices while also giving rights to both parties.

Technocrats also insisted that the social sector was the least efficient portion of the Mexican economy, attracting only 1 percent of the $9.2 billion in investment in 1991. They felt that high unemployment and chronic undercapitalization would be best eliminated by encouraging migration out of the countryside, towards various "employment sinks" such as the burgeoning industrial sector in the Mexican north, or it was often only implied but never stated specifically—migration beyond the frontier into the United States. In the post-privatization visions of the more technocratic reformers, subsistence staples that were produced on ejido lands would be replaced by more "competitive" imports from the U.S., Europe or Canada, while niche and specialty crops would result in a competitive advantage for Mexican agriculture as a whole.

The *ejidatarios* in San Lázaro, however were not generally engaged in staple crop production, but instead used their ranching and farming activities in a mix of cash and staple crop production. Cattle proved to be the ultimate cash crop, with forage production on the Santa Cruz River floodplain supporting the strategy. The sale of apples as well as winter or summer time vegetable crops brought income during periods between the purchase and sale of calves to intermediary buyers. While the ejido does not reflect the vision of the reformers, the reform of Article 27 has altered the local system of tenure dramatically. It rendered the system of collective organization useless by encouraging small group and individual-level decision making rather than collective action. At the same time, the reform built in legal avenues for the transfer or titles or the lease of property rights. In so doing, it also created a *de facto* water rights market whereby the more capitalized farmers could tap into groundwater or subflows rather than rely upon his neighbors to maintain the old *acequia* system. These radical system-wide changes were also both imposed externally and desired internally. When combined with the economic crisis that hamstrung producers' options at the farmgate, Article 27 reform was a powerful incentive for change at the local level as witnessed by new leases and land sales.

Global Integration: The North American Free Trade Agreement

The neoliberal transformation of Mexico was not just concentrated in the policies of privatization. In fact, the privatization and full gamut of structural adjustment policies were intended to build conditions for the first regional free trade agreement implemented between the United States and a developing country—NAFTA. The North American Free Trade Agreement reduced tariffs and other protective measures that kept Mexican agriculture and industry from direct competition with U.S. and Canadian imports. It was the showpiece of Salinas' administration, and perhaps that of American president Bill Clinton's first term. NAFTA altered some fundamental aspects of Mexican agricultural economics at the local-level in San Lázaro, even though the region was already heavily articulated on the close, U.S. market for feeder calves. NAFTA altered the source and pricing of inputs for livestock and cash crop production. It also changed the dynamics of small farmer associations that would have been able to lobby and effect change in Mexico's partron-clientelistic political environment.

Beef imports lost their tariff protection in January of 2003. Cattle and beef producers claimed at the time that imports of boneless beef have increased by 600percent because of NAFTA, displacing Mexican producers. "We are alarmed that meat imports, protected by NAFTA, are suffocating the development of our meat industry," said Sergio Alvarado Garcia, director of the *Asociacion de Engordadores de Ganado Bovino del Noreste* (AEGBN) (SourceMex, September 2, 2002). Though halted for almost 16 months during the Mad Cow scare of 2003, under the free trade agreement, Arizona meatpackers shipped between $50 million and $75 million in boxed beef to the Mexico per year (Steller 2004: 21). But San Lázaro beef sales have been less impacted than other ranches in Mexico or farther south in Sonora, largely because the small scale producers have been selling calves across the border since the ejido was founded (and prior if one counts the Greene period), thereby entering into competition with U.S. producers of calves. Well-capitalized ranches represented by the AEGBN usually produce cattle--usually steers or cows--for the domestic market. San Lázaro ranchers are more specialized into cow-calf operations represented by the six range management groups discussed earlier. Ironically, many San Lázaro community members--even some with their own cattle--purchase their beef in shopping trips to Nogales, Arizona where cheap, packaged meat is available at the Wal-Mart Supercenter, Food City or Safeway (personal communication, September 2002).

Since the 1960s, the ejido has sold its *vaquillos* (calves) and *novillos* (young steers) to exporters in Nogales and Agua Prieta, who then sell the 5 to 8 moth-old animals to North American operations. The animals are then fattened on feedlots in the Southwestern United States, mostly in California, Texas and Kansas (Steller 2004: 21). Currently, *ejidatarios* can still sell their *vaquillos* and *novillos* for reasonable prices (though still considerably lower that previous decades), but the irony is that the beef produced by this system then re-enters the Mexican market as packaged meat and lowers demand for Mexican-reared adult animals sold in the domestic market.

Being at the bottom of the international market for cattle, Mexico's social sector cow-calf operators haven't had far to fall once NAFTA's provisions for beef became effective in 2006. Mexican calf producers already have a distinct advantage over their American counterparts in the southwest, and contribute a lion's share to the U.S. feeder market. This is because it is plainly cheaper to raise a calf in Mexico than in the U.S. Given the costs of vaccinations ($10-15), supplemental feed ($30), water (ostensibly free), range (also ostensibly free); it costs an average of $50 US dollars to raise a calf for sale into the feedlots. As of 2003, the average price of beef at sale was $1.50 per kilo--a good price reflecting high prices in the United States ($3.40 per pound for live beef). In good years, a calf fetches $75-$100 at market, so it is therefore possible that the producer has doubled his or her investment. As the reader will note in Figure 6.2 below, the 2000s have been record years for feeder calf producers (see also Appendix C). Unfortunately, cattle buyers will use many different tactics to lower prices--the most common include the purchase of the animals earlier in the season before they have gained sufficiently, and when ranchers are more nervous about the presence of good forage or continued, expensive supplemental feed.

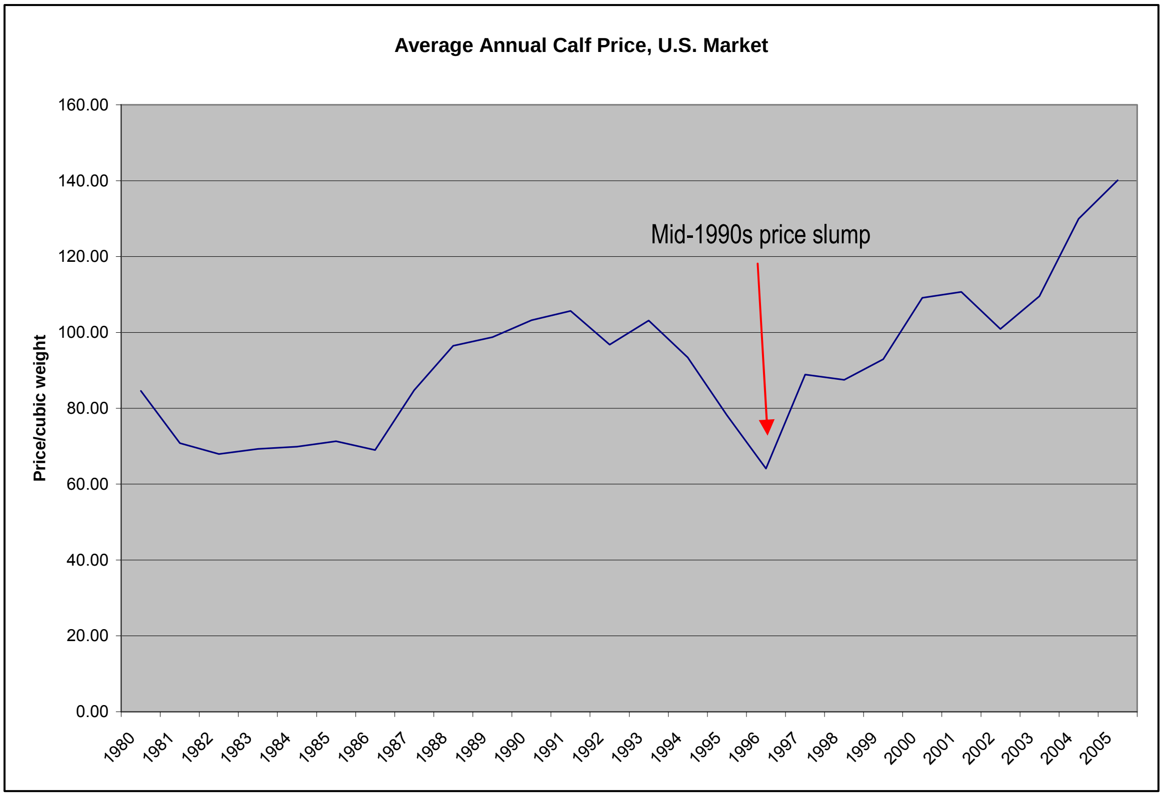

Figure 6.1. Average annual beef calf price on the U.S. market from 1980 to 2006. Source USDA and National Cattlemen's Beef Association 2006. See Appendix C for full statistical summary.

Despite better times for cow-calf operators, however, the long-term impact of the North American Free Trade Agreement is still bad for local rancher-farmers when it comes to their adult cattle. The *ejidatarios* cannot sell their full-grown animals (*vacas adultos*) in local, domestic markets because the importation of large amounts of U.S.-raised beef products into Nogales depresses the price for domestic beef.[12] An adult animal that recently (November of 2000) fetched well over $390 now fetches between $220 and $250. This was the price under reduced tariffs on beef that still provided a modicum of protection for the Mexican industry. In the ensuing drought of 2002-2003, ranchers were most concerned that the animals are not gaining sufficient weight to sell. This would then result in even lowered prices when sold into the domestic market. Under these circumstances, they were supplementing the feed of calves and yearlings prior to selling them in the international market. Supplemental feed includes ground maize, molasses, and various other grains. Alfalfa is also used to increase the weight of the young animals. As an alternative to fattening cattle ranchers may choose to slaughter an adult animal for personal consumption. For example, a rancher might slaughter a 120-kilo adult cow that he, his wife and six adult sons will share. Each will get approximately 20 kilos of beef and other products. This will last approximately 40 days with a half-kilo consumed per day on average (approximately 1 lb.) (personal communication, September 2002).

For farmers in San Lázaro as well as in other areas in the Upper Santa Cruz Watershed, NAFTA's other impacts are felt in their flexibility with raising wintertime vegetables on the irrigated floodplain. In 2003, lowered tariffs on several vegetable crops made wintertime vegetable production (lettuce and cabbage) unprofitable in the Santa Cruz area. While the influx of cheap wintertime vegetables from California, Florida, and other parts of the United States has had an obviously negative impact on farmers in Santa Cruz,

[12] A significant but yet unaccounted for amount of beef imports enter as boxed, frozen beef products—an

ironically the result has been positive for San Lázaro water users. The majority of farmers upstream from San Lázaro use pumps for their water needs during the periods of the year when the Santa Cruz River is at its lowest. This coincides with the March-October planting period for lettuce and cabbage crops. These so-called "wintertime" vegetables were raised successfully only in this portion of Sonora during the hottest months, were more lucrative for local farmers. The pumping of upstream sub- and surface flow, however, causes the baseflow of river to drop precipitously in the San Lázaro reach, leaving so little water in the stream that the *acequia* system largely unusable. Consequently, the period of lowest precipitation--the spring and early summer drought--is the period when demand on the river is highest. As downstream users, the farmer-ranchers in San Lázaro suffer the consequences. In mid-February of 2003, stream capture by the canal system offered flow sufficient to irrigate two fields simultaneously. By late March, as upstream demand increases with the planting of spring and summer-time crops, the *acequia* becomes largely unusable. Hence, the free trade agreement's immediate impact on vegetable growers has meant lowered demands by upstream users in the spring, so increasing surface flows in San Lázaro. Fluctuations in flow due to hydrologic and climatic variables notwithstanding, the rancher-farmers have still be unable to capitalize on these additional stream flows because of the inefficiency of their system and have sought other solutions, which I will detail below.

Downstream, NAFTA has brought about dramatic changes in the other important actor on the Santa Cruz River. Though its boom was foretold decades before with the 1965

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illegal practice according to the Ministry of Agriculture. These boxed cuts are distributed to *carnícerias*

Border Industrialization Program (BIP), Nogales, Sonora reaped some short-term rewards in industrial growth during the first decade of NAFTA. In the period of 1994 to 2004, the border city jumped from an official population of 110,000 to 160,000, while the unofficial but widely known figures are closer to 250,000 to 300,000--a 50 percent increase (Ruiz et al. 2004: 14). The divided U.S.-Mexican city uses well fields along the Santa Cruz River for a majority of its domestic and industrial water supplies. Nogales, Sonora draws as much as 45percent of its annual water budget from a system that includes an infiltration gallery placed into the shallow subflows at Rancho Parades, just 7 miles due west of San Lázaro and only 3 miles from the community's westernmost fields at Agua Zarca. A series of approximately 50 pumps in two well fields at Parades and Mascareñas augment and pressurize the roughly 10,850 liters of water per minute as it is piped over the hills into the burgeoning city (Ingram, Laney and Gillilan 1995: 70). While Nogales, Sonora also draws water from Los Alisos and Nogales Wash; the Santa Cruz well fields constitute the most important source of water for the population and its *maquiladoras* (factories) that manufacture everything from car parts and electronics to medical supplies. An estimated 36 percent of the city's population (and many of its newest residents) live in vast shanties with little access to water except by delivery in trucks (Morehouse, Carter, and Sprouse 2000: 786).

The city and its industrial output are now a powerhouse for Northwestern Mexico with rivals in Mexicali, San Luis Rio Colorado, and Agua Prieta. Municipal and industrial growth is predicted to continue at exponential rate, if sufficient water supplies can be

throughout Mexico and in so doing, undercut domestically-produced beef.

secured. The *maquilas* supply a large number of jobs to the community and are an important linkage with North American investment. Rhetorically at least, municipal authorities are adamant that a stable water source must be part of the equation and a condition for continued growth of the border city's international manufacturing economy (Ingram, Laney and Gillilan 1995: 52). For these reasons, Nogales presents a special pressure for San Lázaro and Ejido Miguel Hidalgo. In 1999, representatives of one of the largest *maquilas* approached the ejido leadership and attempted to negotiate the purchase of water rights from the ejido. For a variety of reasons, the most important of which was the severe post-September 11th economic downturn, the deal fell through and the company withdrew its offer. While private industry has extended an interest into San Lázaro's water, municipal managers have also brought pressure to bear on community members. In 2000, a group of three farmers raising potatoes in Rancho Agua Zarca were approached by the state water management agency charged with Nogales, the Comisión de Agua Potable y Alcantarillado del Estado de Sonora (COAPAES). The farmers had been irrigating water from the subflows of the river using an illegal (unregistered) pump. The COAPAES officials threatened the farmers with legal action if they did not cease their irrigation, as it was interfering with the infiltration gallery and well field in Parades. While water is life for San Lázaro's rancher-farmers, other political-economic actors in the watershed recognized that it is a necessary ingredient for growth and prosperity for some. Acting within the context of a globalized border region they made that clear to their upstream neighbors.

Governmentus Interuptus: Withdrawing from the Countryside

The combination of macro-economic signals and development policy changes along with local organization and tenure arrangements led Ejido Miguel Hidalgo into a new, but uncertain era. Beginning in the early 1990s, the ejido became more autonomous of the governmental patronage and control that had characterized the social sector from 1930s. Secondly, this led to some obvious changes in the way the community governs itself as well as in the response of individual households to shifting economic needs. While many scholars have characterized Mexico as a land of bureaucrats and patron-clientalist practice (e.g. Bennet 1995; Cornelius, Craig, and Fox 1994; Cockcroft 1990; Fox 1997), the 1990s could truly be the era of the great pullout of government involvement from Mexican lives. This had some important environmental and social consequences for *ejidatarios* in San Lázaro.

Beginning with the late 1980s and continuing into the 1990s, the Mexican federal government began an inexorable rollback of services and investment in the countryside. That abandonment began with the rollback of federal agricultural subsidies in the countryside and their replacement with token welfare programs such as *Programa de apoyos Directos al Campo* (PROCAMPO) or the cash payments program known by its acronym PROGRESSA. A more important replacement for federal agricultural subsidies was the $13.3 billion in remittances from migrant laborers abroad (Coronado 2004: 1). Despite the substitutions, the Mexican Federal Government has removed or reduced federal subsidies for rural electricity, telephones, basic road infrastructure, medical care, fertilizers, and basic staples production.

For *ejidatarios* in San Lázaro, these rollbacks meant dwindling credit for agricultural investment—such as 48 hectares of highly productive apple orchards in the floodplain of the Santa Cruz River. Lack of investment and credit for maintenance of the *acequia* system also impeded its usefulness for agricultural purposes—ultimately contributing to the abandonment of the apple orchard and ceasing production of drought-period livestock fodder as well as supplemental cash crops. Of the important signals broadcast to the ejido, this one has been among the strongest and most impacting, simply because of the implications for cattle production.

By the late 1980s and early 1990s, the floodplain fields were being abandoned by a considerable segment of the community. Community leaders estimate that upwards of 75 percent of the previous tenants on the floodplain were no longer farming or had leased their lots to neighbors or outside interests. In 1996, wealthy vegetable grower leased fields just four kilometers away from San Lázaro. With water illegally pumped from the floodplain alluvium, he began growing commercial wintertime crops for the Hermosillo, Nogales and Magdalena markets. Figure 6.2 below illustrates the trend in agricultural zone land transactions from 1980 to 2003. Since the lease or sale of land before 1992 was—at least in theory—illegal, data from this period are anecdotal (gathered from ethnographic interviews with farmers active in this decade). Data from the period between 1992 and 2003 were gathered from an examination of ejido records made by the author with assistance from a former ejido president. Note that due to the seriousness of the charge, land sales are only acknowledged in post 1992.

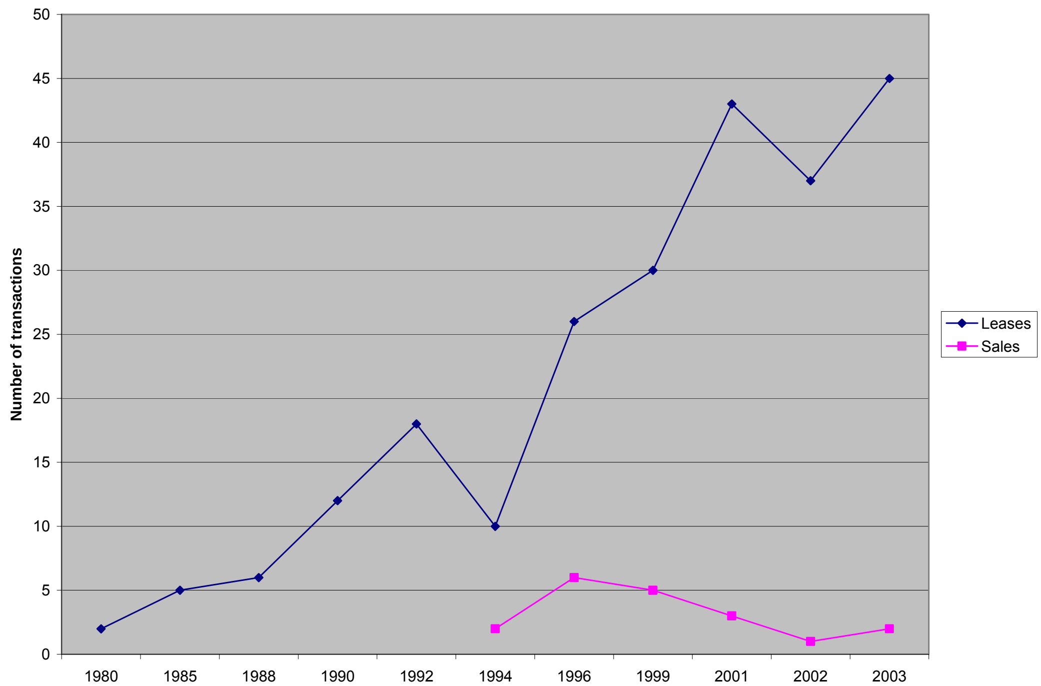

Figure 6.2. Agricultural land transactions from 1980 to 2003. Sources: ethnographic interviews conducted by the author (2002, 2003, and 2006) and untitled ejido records.

Behind the shift is the Mexican government's move towards increasing "rationalization" of the ejido system and its resource-use. Government programs were designed to bring the ejido sector into "alignment" with other Mexican agricultural producers privatized credit, land and water. The last item, water, has been a turning point for the shift in land tenure along the floodplain. Water rights in an *acequia* system are communal by default since all *parciantes* are given an allocation of the river water dependent upon the labor they put in to maintaining the system. Well water is subjected to private property rights once it is extracted. A well owner cannot sell the water below ground, but can offer for sale their rights to the resource. San Lázaro is yet another example of this shift.

In fact, the ejido has already negotiated the sale of a portion of their water rights to a local mining operation to help capitalize the well refurbishment. This was actually suggested by officials in the Mexican federal government. The new system appears to be encouraged by the federal government as well as by the presence of other economic activities in the area.

***Las Manzanas*: the Apples**

Water, however, must be applied to appropriate and profitable crops for it do any good. Without supported inputs and well-articulated markets, no amount of water—private or public—will do any good. But economic signals and inconsistent policies of agricultural development made good crops to hard to come by and reduced the efficacy of particularly lucrative ones over time. Of the crops raised on the floodplain, apples provide an excellent example of these mixed economic signals at work and impacts generated at the local level. From the 1940s to the early 1990s, San Lázaro and its upstream neighbor, Santa Cruz raised apples for domestic markets. Locals recounted how wholesalers in trucks and carloads of families would travel to the two towns to purchase apples from the many hectares of orchards along both sides of the river. As one *ejidatarios* involved at the peak of apple production, "*eran muy famosas, la huerta de manzanas*," they were very famous, the apple orchards (personal communication, November 2002). *Ejidatarios* reported that people came from Hermosillo, Mexicali, Nogales, Magdalena (personal communication, September 2002). In 1962, 48 hectares of the agricultural zone were devoted to the production of "Red Delicious" apples for the Sonoran market. In the 1969 season alone, over 64,904 kilos of apples were harvested from San Lázaro's orchard. Of those, 36,108 kilos were shipped to Mexico City, while 28,796 were shipped to Hermosillo, Sonora, and 7,238 kilos were shipped to Mexicali, Baja California (untitled ejido records). But apples, especially those hybrids such as "Red Delicious" are highly susceptible to a variety of diseases and pests that decrease yields. In fact, the original stock for Red Delicious apples has been continuously cloned and grafted on to hardy crabapple stock since it was first discovered in a Pennsylvania farm field in the 1920s (Pollan 2001: 47f). In the 1980s, the de la Madrid and later Salinas governments removed some subsidies for pesticides and fertilizers but more importantly sold off the state-controlled manufacturing plants responsible for the production of these chemical inputs including plants in Hermosillo and Mexicali that were sold to a holding company for Dow Chemical. The final dénouement for the San Lázaro (and Santa Cruz) apple production was a post-NAFTA influx of Washington apples, coupled with the opening of a major highway linking Chihauhuan producers with Sonoran markets in 1994. Furthermore, without regular flood irrigation provided by the *acequia* system, the trees began to physically deteriorate.[13]

The story of the apples provides a case study in how the removal of state support led to removal of a critically important livelihood, one that had impacts spread across the community. As many as 65 out of 114 *ejidatarios* shared the duties of packaging, irrigating, applying chemical inputs, and the entire ejido shared the profits from the sale of boxes of apples. With the removal of state funding for chemical inputs and the inability of the Mexican government to quickly support repairs on the irrigation system has meant a loss for

[13] Tom Foley, Democratic congressman from Spokane, WA was speaker of the house in 1994 when NAFTA

the community of one more component in its mix of livelihood strategies. The ejido was unable to compete on the international market once NAFTA allowed Washington apples to enter the Mexican market, and without reasonable infrastructure improvements--the bad road between the communities in their markets to the South, Chihauhuan producers have been able to dominate their domestic competition.

Climate Variability: *La sequia y años lluviosos*

Changes in governmental support, international linkages, and local land tenure decisions only bear part of the responsibility for the situation in which San Lázaro's rancher-farmers now find themselves. As discussed at length in Chapter Two, the environment is no passive agent of change. In combination with economics, climate in particular has played a major role in the successes and failures in San Lázaro and the rest of watershed. The semidesert grasslands that San Lázaro's ranchers depend upon are among the most sensitive plant communities to drought and precipitation cycles, hence any shift in rainfall across the region is profoundly felt, especially when cattle growers are already sensitized by other economic realities such as lack of cheap supplemental feed, low domestic cattle prices, currency instability, high interest payments, or household crisis. Inter-annual and decadal variability in precipitation and temperatures are, however, the norm for climate in the region. This means that ranchers must be prepared to adapt to sudden changes in forage availability, even when those changes are not advantageous in the short-term. If rigidity is created by

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was finally passed. His former district continues to produce some of the largest crops of apples in North other conditions, then social vulnerability to the negative impacts of climate change is increased in the group.

A "wait and see" approach is common among ranchers on both sides of the border, but climate variability in the greater Southwest and Northwestern Mexico demands much more adaptive management strategies. Cattlemen must be willing to purchase supplemental feed, move the animals, or sell off herds if conditions are bad, even for a season. If a grower waits too long, cattle weights may be too low to fetch a reasonable price, or the market might be flooded with other animals being sold off by desperate ranchers. Furthermore, ranchers in San Lázaro sell most of their calves over the border to the U.S. market for feeders. When drought strikes and U.S.-based ranchers sell off their herds in response, the local demand and price for calves or yearlings drops precipitously, regardless of the national price for feeder animals. A yearling steer can fetch as little as $300.00 in a bad year and $800.00 in a good year. A calf usually sells for about $300 if it is in good condition but can drop to less than $100 offered by a cattle buyer if the animal appears diseased or weak from hunger. These swings in price are severe enough to encourage ranchers to remain conservative when deciding whether to sell animals in a crisis. The field of decision theory weighs the costs of changing management against the risks of inaction or of making a bad decision. In an acknowledgement of the difficulty in making decisions based on an uncertain future, the best decision sometimes can be to wait out a dry spell—if it does rain in time to save a rancher's herd and livelihood for another year.

America.

While there is little consensus on what exactly is happening to climate in the region, researchers feel strongly that change in seasonal, annual, and decadal precipitation patterns is in the cards (Michael Crimmins, personal communication January 26, 2006). Recent historical climatology for neighboring climate divisions in Arizona bears witness to some obvious and not so obvious trends.[14] Three decadal periods of drought occurred in the 20th century: one at the beginning of the century, one in the 1950s, and again in the late 1990s (see Figure 6.3). Palmer Drought Severity Indices[15] for each period were in the moderate to severe range for Climate Division 7 in which sits the U.S. portions of the Upper Santa Cruz Watershed. Temperatures in the region are quite variable, but beginning in the 1980s, temperatures began a rapid climb, with the second and third earliest springs on record occurring in the 1995-2005 period (see Figure 6.4).

Temperatures tend to correlate with precipitation, which shows signs of change too. As the trend-lines in Figure 6.4 seem to indicate, seasonal variation in precipitation patterns has shifted across the region in two somewhat subtle ways: 1) in recent years, winter and spring precipitation has lessened in frequency--especially in late season storms; and 2) summer precipitation has shifted towards greater intensity of fall precipitation and more variable summer precipitation delivery. ENSO-driven precipitation patterns, moist El Niño-

[14] Mexican climate data is more highly aggregated, and in most cases entirely lacking for the Upper Santa Cruz WatershedUpper Santa Cruz Watershed. This has meant that I have relied heavily on data from Arizona, particularly Climate Division 7 an area encompassing the U.S. portions of the Santa Cruz River Valley and San Rafael Valley. The trends that these data demonstrate are therefore considered close approximations and/or broad regional patterns. In some cases, data are interpolated for the entire state of Arizona but indicate trends that are similar to Sonora since the two states are influenced by similar weather patterns.

[15] The Palmer Drought Severity Index (PDSI) is used to measure drought conditions. In short, the PDSI combines temperature, precipitation, and other factors to index medium-to-long-term variations in soil

phase winters followed by neutral or dry La Niña-phase winters, may also be shifting with changes in the occurrence of the Pacific Decadal Oscillation (PDO) as averaged across Arizona's six climate divisions (Garfin and Emanuel 2006: 10). Although not entirely clear, the phasing of the PDO seems to lock the ENSO patterns into more or less stationary phases for example, greater frequency of La Niña events for example leading to drought conditions. This gives the region its historical pattern of decadal droughts followed by above average years. The drought periods at the turn of the 20th century and the 1950s are potentially examples, although climatologists did not know of the PDO until recently and therefore have not been measuring the appropriate sea surface temperatures (SSTs). In 1995, a ten-year drought cycle began that appears to correlate with a PDO cool-phase, lending credence to the theory (McPhee, Comrie and Garfin 2004: 20).

Oral histories gathered in San Lázaro tend to confirm these trends and demonstrate the immediate impacts of climate variability or change on rancher-farmer livelihoods. *Ejidatarios* recount that the period of the 1960s and early 1970s were particularly wet, resulting in abundant forage production in the oak savannahs and semi-desert grasslands of the ejido. Cattle production during this period was particularly high (see Figure 6.6 and accompanying Table 6.2). As one *ejidatario* said, "*fueron mas, las aguas y las equipatas en los años y decadas antes, y ahora, esta muy seca, muy triste*," there were more, more rains and winter rains in the years and decades before, and now, its very dry, very sad (personal communication, March 2002). In a survey of 64 heads of households, 58 percent noted that snow was rarer

moisture. In PDSI, positive values indicate wet conditions and negative values indicate dry conditions (McPhee, now than previously. Some younger members of the community could hardly remember seeing snow at the 3,560-foot altitude of the town. When the author drove to San Lázaro for the first time in 2001, a brutal drought had left the roadsides strewn with dead livestock, although a subsequently good winter in 2002 alleviated this situation until the drought resumed the follow year.

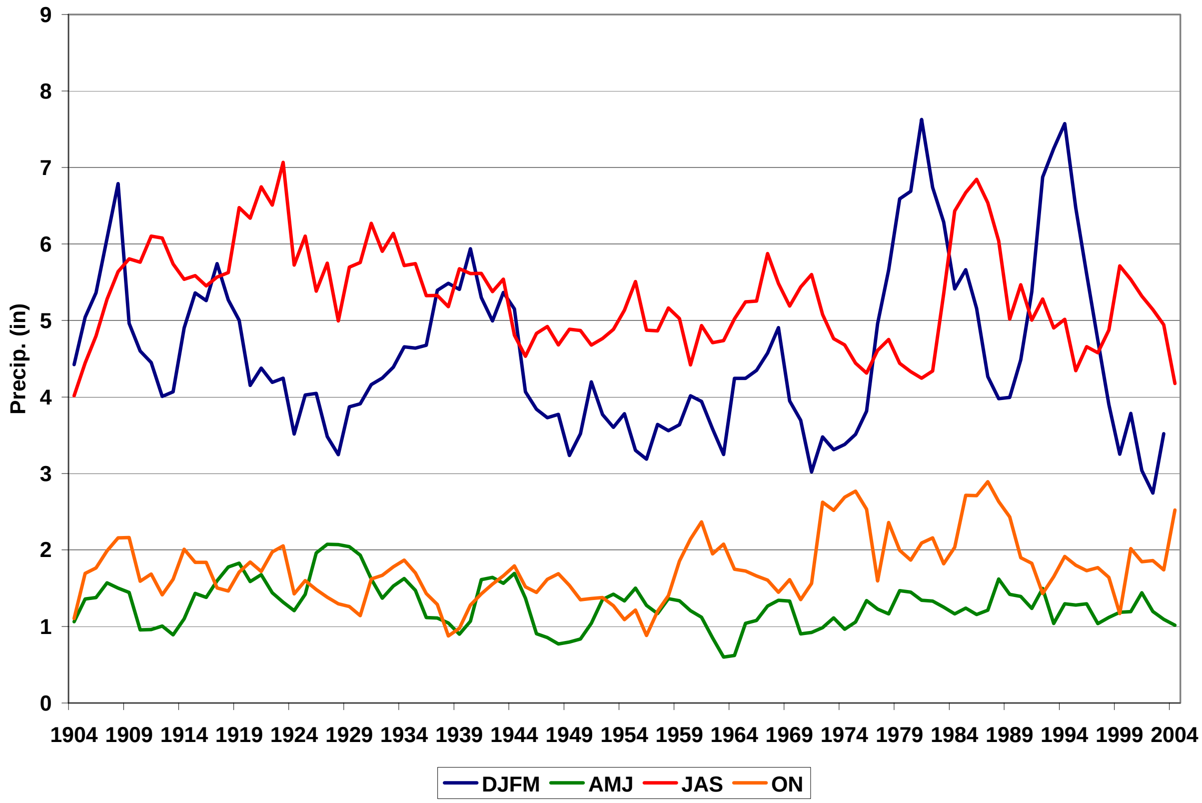

Figure 6.3. Trends in seasonal precipitation from 1904 to 2004 for Southern Arizona (DJFM=Dec.-Jan.-Feb.-Mar.; AMJ=Apr.-May-Jun.; JAS=July. -Aug.-Sept.; ON=Oct.-Nov.). Source: Michael Crimmins, University of Arizona Climate Science Applications Program.

Comrie and Garfin 2004:6).

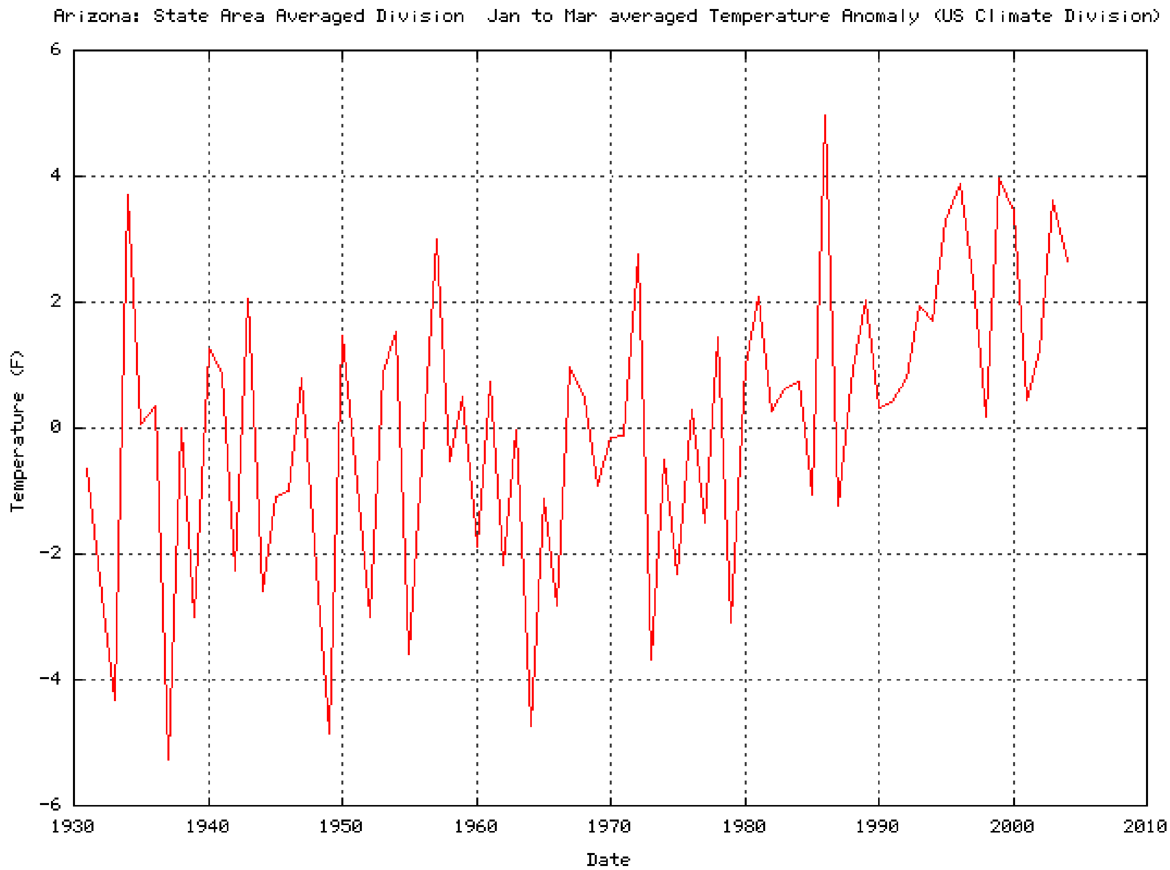

Figure 6.4. Seasonal temperatures 1930-2005 for Averaged Climate Divisions of Arizona. Source: US Climate Division, NOAA. Data compiled by Michael Crimmins, the University of Arizona Climate Science Applications Program.

The Consequences of Rapid Rural Transformation

The landscape and political economy of San Lázaro have been transformed over the past two decades. Since the 1980s and especially in the 1990s, the political ecology--here defined in terms of the distribution of power and its ecological effects--has shifted dramatically away from the communal and towards the individual. This has meant that risks that were shared, and environmental consequences that were more or less equally distributed, are now placed squarely on the backs of individuals and their households. It is here that the economic reconfiguration of the community has created new and different classes of landowners and landless, with a diversity of livelihoods within each broad category. This section discusses the ways these classes have been differentially impacted by macroeconomic and environmental change. The environmental changes include drought, flooding, and changes in stream morphology.

Among the most important consequences of the transformation of the countryside in the past decade are leasing and outright land ownership by outsiders which has increased since the ejido was reorganized in the early 1990s. Where before the ejido's roughly 104 member households owned a share each, that number has dropped as of 2004 to 88, with the remainder coming overwhelmingly from purchases by investors from Santa Cruz (22 out of 26). The remaining four purchasers originate from Hermosillo, Nogales, and Sinaloa (the latter making two purchases of land use shares). Unfortunately, there are no comparable data from prior years as the most recent agricultural census was conducted in 1990, before the reforms of Article 27 were enacted at the local level. Leasing too has become substantially more important for the community since it was made legal in 1992. In San Lázaro, Article 27 reform and restructuring has meant that agricultural land on the floodplain was parceled out between community members-then sold and resold into larger shares for some, smaller for others. The results are obvious ten years later. Only twelve out of 104 *ejidatarios* still actively farm on the floodplain—roughly 12 percent of the total ejido. Fewer members of the ejido claim to gain livelihood from ranching or agriculture in general (see Figure 6.5). Commercial interests from Hermosillo, Nogales and Santa Cruz have purchased some of the agricultural lands for wintertime vegetable production (although the maximum parcel owned by one interest was 4 hectares). Of those surveyed who still were members of the ejido share (58 out of a sample size of 69), 46.3 percent no longer had relatives farming or renting parcels in the floodplain, hence even kinship relationships that normally reinforce ties to the land do not exist with regards to floodplain production.

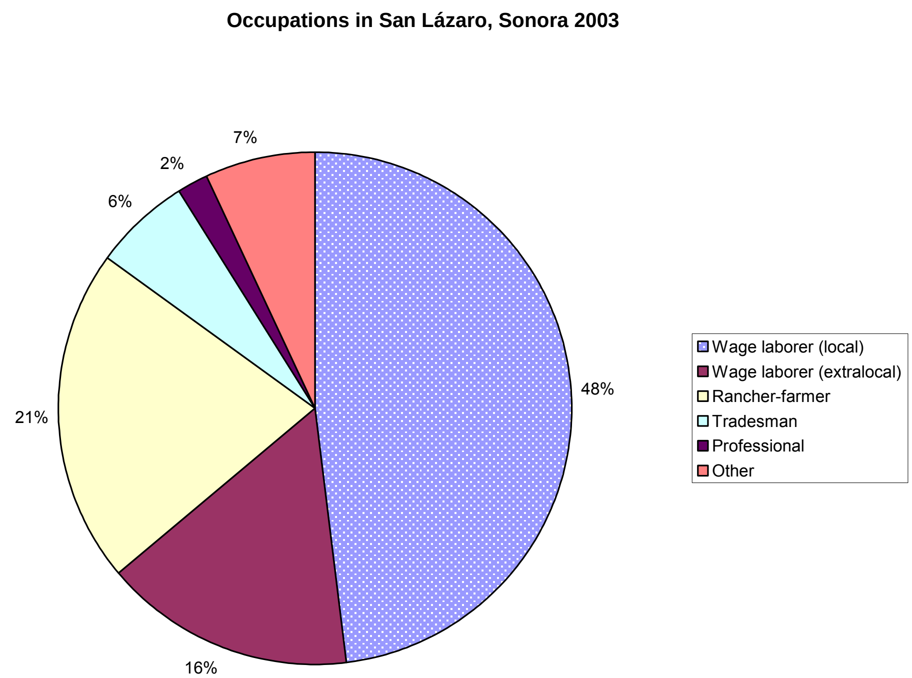

Figure 6.5. Occupations in San Lázaro in 2003. Based on April 2003 survey of households.

Membership in the ejido is significant for more than economic reasons. Those who possess ejido land today can implicitly claim a link with what is widely perceived as a heroic, revolutionary agrarian past, while at the same time arguing that landless families in the community did not play as important a role in the struggle for land. As one ejido member put it succinctly, "*construimos una comunidad agraria de casi nada*," we constructed an agrarian community from almost nothing (personal communication, May 2003). And as one former ejido leader put it bluntly "*los hijos nuestros no saben nada del tierra ni lucha que hicimos aqui, no saben que es nuestro*," our children don't know the land or how we struggled here, don't know what's ours" (personal communication, December 2002). The possession of ejido land therefore provides a certain status and reinforces a social distinction that exists between *ejidatarios* and other community members.[16] Few in San Lázaro openly use this distinction but rather complain about the distinction between locals and those from outside of the community who now own an appreciable portion of it. When asked about it, the *juez de campo* complained that many ranchers from Santa Cruz owned rights to the ranges but didn't live in the community (personal communication, January 2003). The ejido share also gives some food security to those who can cultivate their plots along the floodplain--though many crops there are strictly for forage and not domestic household consumption.[17]

Linking these social conditions to land management is more difficult because of a lack of data on range conditions and hydrology. Range conditions in the ejido, as in ejidos across Mexico, were sporadically if ever measured. The two most important government managers of the ejido's operations, Banco Ejidal and Banco Nacional de Crédito Agrícola (Banco Agrícola), sent range scientists to assess the ranges only a half dozen times in the last twenty-five years. But they were not the only ones. COTECOCA, the range assessment arm of the federal ministry of agriculture also visited—at least twice—to determine the "carrying capacity" of the pastures and to dispense advice to local ranchers. For the entire ejido, the carrying capacity was determined to not exceed 4,000 Animal Unit Months

[16] Being an ejidatario also means that an individual can participate in government programs that are denied to landless campesinos, even though these programs have been curtailed in the past two decades. Lastly, ejido membership allows individuals access to leadership in the community, which is dominated by ejidatarios (Nuijten 2003: 482; Sheridan 1988: 143f).

(AMUs). The amount of permissible livestock grazing in both Mexico and the United States is generally are expressed in terms of animal units per area or total animal unit months (AUMs). One AUM is the amount of forage required by an animal unit (AU) for one month, or the tenure of one AU for a one-month period. If one AU grazes on an area of rangeland for six months, that tenure is equal to six AUs for one month or six AUMs. In general, the number of animal units, multiplied by the number of months they are on the range equals the number of AUMs used.

The ejido was also visited on an annual or seasonal basis by dignitaries from local government in the municipio of Santa Cruz, by the Ministry of Agriculture, the National Agrarian Commission, the National Peasant Confederation, and representatives of the State of Sonora. *Ejidatarios* were integrated into a multi-layered system of managers, from the Federal Government to the financial institutions, to state and local political bosses. Each relationship encumbering certain obligations upon which whole systems of survival and livelihood depended. Conflicting, often confusing patron-clientalism ruled the ejido for nearly 30 years in nearly perfect lock step with over exploitation of the landscape upon which the community ultimately depended. Local knowledge of the landscape was very often ignored in favor of top-down decision-making processes that benefited those higher in the state's trophic levels.

For instance, cattle stocking rates were very often determined by agronomists employed by Fomento Ganadero de Sonora, but actual credit was provided by Banco Ejidal.

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[17] Footnote: Extra forage is still vital for cow-calf operators and can thus replace a large expenditure on

Administrators from the former sought to keep stocking rates in line with SAHR recommendations, while Banco Ejidal management pushed to stock at higher levels, in order to return a profit on the initial investment. *Ejidatarios* responded to the latter signals, despite local indications that there would be dire long-term impacts from overstocking the ranges. The demands of the Banco Ejidal—the primary source for funds for the community—could not be ignored without seriously compromising the relationship and ultimately endangering this vital source of capital. Ejido members felt that the bank made decisions based on short-term economic gain, federal-level quotas, and personal ambition, the consequences be damned. Cattle stocking numbers, in fact, did peak during the period of bank rule in the community (see Table 6.2 and Figure 6.6). And one simple indication of the severity of the corruption was the behavior of the bank upon its closure in Cananea in late 1994. According to one former bank manager, nearly all of the original records of 35 years of ejido administration were destroyed or ferreted off by employees (personal communication, October 2002).

purchased hay in lean months. This makes its production an important contribution to household livelihood security, although not in the traditional use of the term.

Year	AMUs Ejido Miguel Hidalgo	AMUs Ejido Santa Cruz
1967	7,226	No data
1972	6,556	No data
1974	7,932	No data
1978	6,003	No data
1984	7,070	No data
1990	5,006	No data
1996	6,735	3,162
1997	7,429	3,071
1998	7,279	3,331
1999	7,206	4,431
2000	6,329	3,498
2001	7,538	3,276
2002	7,517	3,840
Total	**82,600**	**24,609**

Table 6.2. Cattle stocking for Ejido Miguel Hidalgo and Ejido Santa Cruz, 1967-2002. Sources: Fomento Ganadero--Estado de Sonora; Contratos Apetura de Creditos--BANRURAL, Censo Ganadero--INEGI, original field research.

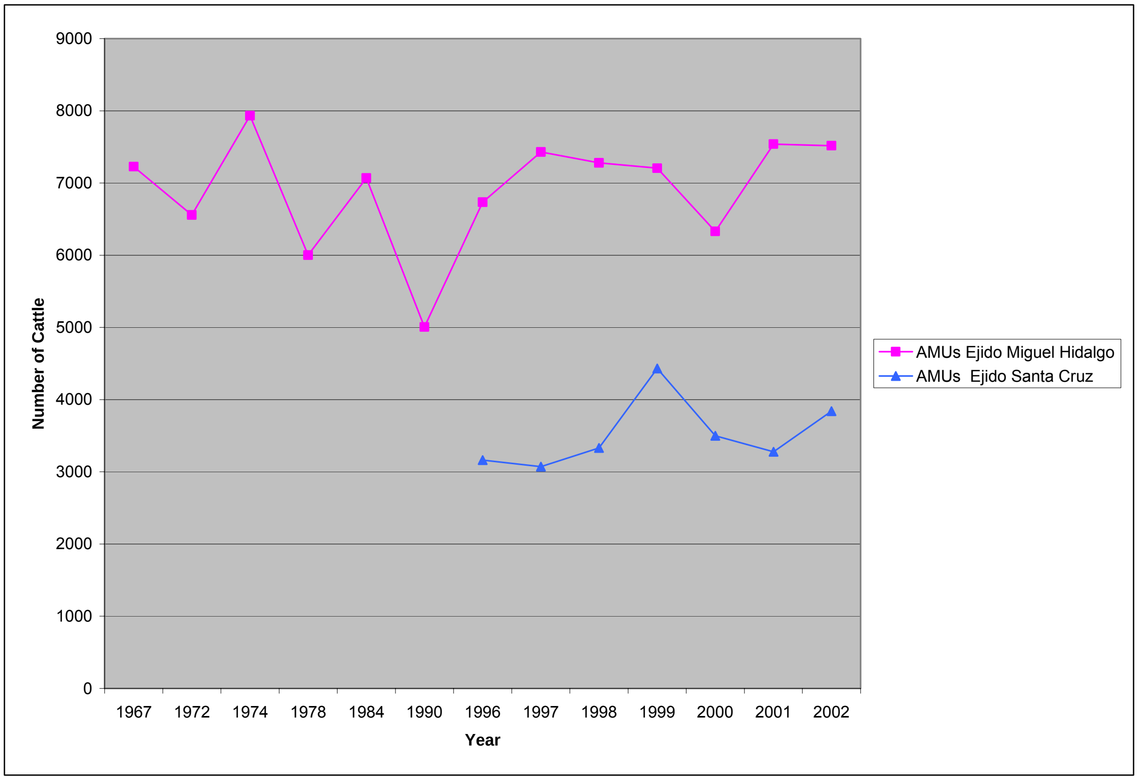

Figure 6.6. Cattle stocking (in Animal Management Units) for Ejido Miguel Hidalgo and Ejido Santa Cruz, 1967-2002

The ultimate impact of this cycle of over exploitation was the impoverishment of rangelands and *ejidatario* livelihoods. Cattle numbers peaked in the mid-1980s, shortly before the Banco Ejidal pulled its operations from the ejido in 1988. Since the 1980s, rangelands have displayed high rates of erosion and replacement of bunchgrasses with disturbance-tolerant plant species such as Mexican prickly poppy (*Argemone mexicana*), Russian thistle (*Salsola iberica*), as well as unpalatable species such as mustard (*Brassica* sp.), and red cheat grass (*Bromus tectorum*). In some areas, oak and mesquite have begun to replace open grassland with intermittently dense savannah (Tellman and Hadley 2003: 16), although fire suppression may also be responsible. In its current state, the ranges of Miguel Hidalgo cannot support the numbers of livestock it did in previous decades. Oral histories from long-time inhabitants contrast contemporary conditions with the last years of the Cananea Cattle Company in the 1950s, when even during a severe decadal drought, ranges could support high stocking numbers and even hay cutting at high elevations. Said one resident, "*en varios partes, la zacate era mas alta que nuestras caballos*," (in some parts, the grass was higher than our horses) (personal communication, January 2002). No doubt, some hyperbole is to be found in the recollections of the oldest *ejidatarios*, but the comparison is clear: range conditions are not what they used to be in the early decades of the community. A survey of 69 households revealed a common (82 percent) perception that water runs off of the land more rapidly than prior periods, that soil erosion is common, and that ranges are not as healthy as they once were. Those surveyed also almost universally blamed drought for the changes (96 percent).

The influx of newcomers to the ejido may be changing its range condition more than during the *colectivo* period. Although the cattle numbers may be down for the entire ejido overall, animals are now concentrated within specific pastures designated for the groups. At the very least, social frictions from the new competition for resources is evident in the speech of some long-time *ejidatarios*. As one rancher noted: "*de los que rentan o compran derechos de ahí viene la sobresplotacion, pero nosotros tratamos de seguir las normas del ejido. Ellos traen otra vision diferente, en poco empresarial. Son personas que no cuidan su terreno, es por eso que compran aquí y alla, siempre haciendo lo mismo*," of those who rent or buy rights here comes the overexploitation, though we [meaning long-time, local *ejidatarios*] try to follow the ejido rules. They have a different vision entirely, a little more business-oriented. They are people who don't care for the land, that's because they buy here and there, always doing the same thing (personal communication, September 2002). Another rancher noted: "nosotros conocemos el manejo desde hace tiempo ya sea del agostadero, potrero. Hay personas que tienen mas de 200 cabezas y nos preguntamos ¿de donde sacan tanto terreno para meter esa cantidad de animales y abastecerlos en comida y mantener ese terreno en buen estado?" We know how to manage [our range] since we know the range, pasture. There are people who have more than 200 head and we ask them: where are you going to get all of the land to put that quantity of animals and give the food to them and still keep the land in a good state? (personal communication, September 2002).

Water Resources Transformations

Cattle stocking along the Santa Cruz River riparian area has been and continues to be common, leading to changes in species composition of the galleried forest. Oral histories tell of a stream bordered by large cottonwoods (*Populus fremonti*), but without Goodding willows (*Salix gooddingi*), and seep willows (*Baccharis salisoides*), both highly palatable species for livestock. Despite the short-term geomorphological impacts, however, perennial surface flows have continued, and until the 1980s, down cutting of stream banks minimal. These latter, significant environmental characteristics would change drastically when the long-term time-lagged impacts of upland overgrazing on stream fluvial geomorphology finally came home to roost in the 1970s and early 80s. A series of floods began the process of stream entrenchment that dropped the channel nearly 15 feet below the floodplain.

The first entrenchment occurred in the winter of 1977-78. Swollen with heavy rains from a series of Pacific winter fronts likely associated with a wet phase of the El Niño Southern Oscillation (ENSO), the Santa Cruz River and its ephemeral tributaries overflowed their banks and became a torrent as they approached San Lázaro. The Southern Pacific railroad line, running between Cananea and Nogales, Sonora ran parallel to the river at this point, then crossed it just downstream from a series of box canyons (referred to locally as "el Cajon"). The railroad company had constructed a heavy steal and wood bridge at this crossing point. After a steep fall in elevation through el Cajon, the rushing waters, upon encountering the cement footings of the bridge, cut deeply into the banks of the river, undermined the footings and toppled the bridge within a few hours. The floodwaters also cut into the intake of the old filtration gallery, filling it with sand and reducing the flow by a third. The infiltration gallery flow, as discussed in Chapter Two, contributed to consistent flows into the ejido's *acequia madre*, and so was a vital component in the irrigation system for the community. Additionally, part of the system's settling tanks that allowed corrosive and potentially constricting suspended sediment to fall out of the irrigation water were destroyed. A second, even more powerful, flood in the winter of 1983-84 completely destroyed what remained of the gallery, intake tubes, settling tanks, and irrigation intake. *Ejidatarios* managed to reconstruct a small impoundment just upstream from the infiltration gallery to capture the meager surface summertime flows, but down cutting and fickle surface flows made a difficult situation worse. According to the *ejidatarios* who were directly involved in floodplain agricultural zone management, for lack of irrigation water, fields at the end of the line went fallow between 1987 and 2003 (personal communication, July 2002).

The ejido petitioned the federal banks as well as the Agricultural Ministry for assistance in restoring the system, but neither responded in a timely fashion. It was a case of bad timing as the local environmental disaster occurred during the financial crisis of the 1980s described previously. Already by the mid-1980s, the de la Madrid government had begun to withdraw from spending on development of the countryside. Orders from the federal level were to minimize spending on new capital improvements or even to existing infrastructure in rural areas. With the *ejidatarios* unable to show an immediate "return on the investment" of rebuilding the filtration gallery, officials from the Ministry of Agriculture refused to support funding any efforts to rebuild. Without cash to repair the irrigation system, floodplain fields that produced warm season forage crops for livestock production, or even cash crops (a direct benefit to local households and not bureaucratic economies) were left high and dry during droughts.

By the 1990s, former ejido leaders reported that the infiltration gallery tubes were filling with sediment of sufficient quantity to stop flows altogether for most of the entire growing season (personal communication, July 2002). *Ejidatarios* took things into their own hands and collected sufficient money and labor to extend the intake upstream well past the clogged filtration gallery. Using sandbags, woven brush, and rocks, a small group of active farmers constructed a second *toma directa* or intake for the *acequia*. While this managed to increase water flows to the agricultural zone, it was only a partial solution when either winter or summer rains were scarce. Many of these improvements were blown out in another ENSO-driven storm in the winter of 1992-93, forcing more improvements to the system. With onset of drought in 1995 and extending well into the present, water in the *acequia* rarely flows the full seven kilometers length for more than a few weeks out of the year. Transmission losses on this canal are also a constant issue, especially when flows are slight. Tapping into funds from a Zedillo-era program, *Alianza para el campo*, the leadership of Ejido Miguel Hidalgo has planned to line 5-6 kilometers of the *acequia* with cement (personal communication, July 2002). Although funds were promised in 2002 by mid-2006, this project has not yet been funded or implemented. The lack of irrigation water has had great economic repercussions for some, though not all, rancher-farmers utilizing the pastures of San Lázaro. As mentioned previously, the ranchers' access to intensively farmed bottomland means they can produce one of two types of crops: supplemental forage for their animals (alfalfa, sorghum, rye grass, Bermuda grass), or cash crops that allows them to purchase forage (cilantro, onions, garlic, corn, beans, radishes, lettuce, cabbage). Without access to regular water, neither of these types of crops may be grown easily, though alfalfa, with its tolerance of greater drought has made it more popular in recent years, surpassing the production of cash crop vegetables.

The access to supplemental forage is critical for successful ranching and especially cow-calf operations in the watershed. The link was described to me by one of the most active rancher-farmers still utilizing the agricultural zone.[18] The average cow will consume one third of a bail of alfalfa or grass hay per day for an average of three months out of the year. That supplemental feed is especially important during calving in the spring and early summer months. It is also critical for a small cow-calf operator to have a few bails of hay on hand during the dry spring foresummer drought and early summer, to tide the animals over during the hottest and potentially driest part of the year when range grasses and forbs are sparse. A rancher-farmer cultivating two hectares of land can produce one hundred and twenty bails of hay if they have access to about 6 days of irrigation applied during the critical periods of seeding, mid-crop fertilization, and prior to cutting. No farmers own a bailer, though they can lease one for the equivalent of 35-50 bails of hay. If the weather is warm, the time from seeding to harvest is 38 days. Alfalfa and grass hay can be cultivated during the fall and winter, although alfalfa fares better with cold weather while grass will produce better hay in response to warm summer months and abundant moisture during the monsoons. But high soil moisture is critical to grass hay as much as for alfalfa hay. If a bail of hay is purchased from an outside source, the cost can range upwards of $100 pesos, while if a farmer produces his own, the cost is between $50 and $30.00 pesos, depending upon the weight and color of the hay. The color of the hay is an indicator of its protein value for the livestock (personal communication, September 2002).

There is a distinctly new economic configuration for farming on the bottomland. The economic reorganization of the ejido has created a diversity of classes of landowners: those who control lands on the floodplain, and those who do not, although they may still be legal members of the ejido. When the ejido was organized as a *colectivo*, the floodplain produced forage, vegetables, pasture for dairy cattle, and apples, and was divided among the ejido households into equal shares. A division boss or *mayordomo* oversaw the operations of this zone. Following the restructuring of land tenure in the early 1990s, many *ejidatarios* sold or leased their rights to floodplain lands, due to the lack of water and the cost of unsubsidized inputs. Where prior to 1992 each ejido household was given 4 hectares of the floodplain, now the average size of a holding is 15 hectares and only a dozen people still farm (though there are several investors from neighboring Santa Cruz and one from Hermosillo). Now those who continue to farm the floodplain do so at their own individual cost, including inputs of labor and cash for improvements to the *acequia madre*. According to one of the most active farmers, in the fall of 2002, the dozen had invested over $2,000 (US)

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[18] The individual interviewed has a parcel close enough to the start of the *acequia* that he can count on

in hiring a back-hoe and purchasing culvert to place portions of the *acequia* below ground and out of they way of future floods (*ibid.*).

The lack of regular flows in the *acequia* and regular irrigation along the floodplain has meant that rancher-farmers have sought the resources to pump groundwater from the floodplain to augment (or perhaps replace) the surface water resources that were a dependable source for the past 100 years (if not more). As with land management and floodplain agriculture, federally driven neoliberal policies again have influenced this choice. Land is not the only resource that has undergone a major transformation in tenure under neoliberalism in Mexico. Water has also become a commodity that can be sold on the market for private gain. The transformation of water from national patrimony to marketable product is part and parcel of a greater, global debate over whether water can be considered an "economic good, subject to the rules and power of markets, multinational corporations and international trading regimes" or alternatively, as a "social good" vital for life (Pacific Institute 2002). The struggles of farmer-ranchers in Sonora, while several steps removed from this debate, are nonetheless compellingly tied to the greater debate.

Since the passage of the *Ley Federal de Aguas* (crafted in 1972 to correct imbalances of water between large landed interests and ejidos), water has been considered a national good-held in trust by the State for the use of its citizens. Water resources were always allocated with the creation of ejidos. Water was tied to land rights, and since both were conferred as usufruct by the Mexican State, *ejidatarios* were given rights to its use. Ejido water, according

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regular and sufficient irrigation water for two crops per year. He has also continued to be the strongest to Article 27 of the Constitution of 1917, must always be used for agricultural purposes, except for a small provision for urban use (Rodriguez Langone 1968: 39). In theory, this was always the case. As with many legal realities as opposed to practicable realities in Mexico, the application of the law produced a different result.

Mexican ejidos frequently found themselves on the other side of conflicts for water rights. Ejidos often leased or illegally sold their water rights, although it was just as common that those with wells or the ability to divert surface flows could simply remove water from ejidos without paying any compensation. Surface waters could be diverted in a permitted process controlled by the National Water Commission; however, little enforcement took place to keep illegal diversions from drying downstream users' water supplies. Most importantly, water technology such as wells, diversions, canals, or even windmills are expensive items to purchase or build. Private and public capital was almost always needed to finance *ejidatarios*' efforts. Most of that capital went through public-sector institutions such as the Banco Ejidal or BANRURAL where corruption and mismanagement were norms. Technocratic reformers in Mexico saw not only an opportunity to remove the barriers to capitalizing water projects with ostensibly less corrupt, private capital, but also an opportunity to rescue *ejidatarios* from predation by both unscrupulous competitors and lenders alike (Whiteford et al. 1998: 393).

As detailed earlier, the ejido had largely abandoned the *acequia* system damaged in the floods because the Mexican government refused to provide loans or capital for its repair.

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voice advocating for repairs to the irrigation system.

Gasoline-powered wells that augmented the canal system were also largely abandoned when their fuel and maintenance costs became prohibitive.[19] In the early 1990s, the motor for one was actually stolen, never to be replaced. Left to their own devices, *ejidatarios* have begun to rent out portions of their floodplain agricultural zone to outsiders from Hermosillo and other areas. These entrepreneurs, better capitalized have gained access to water supplies through the establishment of illegal wells. In the meantime, *ejidatarios* have begun to negotiate for resources to drill their own wells on the floodplain.

Ironically, Article 27 reform gave them the vehicle to do this, In 1992, when the administration of President Carlos Salinas de Gortari implemented the reforms of Article 27, they realized that water resources-particularly subsurface waters-like ejido lands, were of paramount importance to community and individual economic development. But Mexican waters, like mineral resources, are defined as part of the *patrimonio Mexicano*, and hence could not be owned individually, although permits for water extraction could. In liberalizing this system, *ejidatarios* were allowed to apply for permits to extract water for individual or community use if they could show title to the lands above the aquifer. More importantly, they could also enter those permits into a regional market-selling the rights to extraction to anyone within the same basin or aquifer. The trick to this is that the National Water Commission (CNA) has very little data to define these basins or aquifers. Furthermore, extraction could be traded in one location for extraction in a neighboring (though poorly defined) basin. The net result is that the de facto market for water that has been created in

[19] Once the pumps were no longer maintained, they were stolen from their locations or vandalized in place.

Mexico is neither clearly delineated nor well regulated. Furthermore, this policy opened for development and sale, ejido water resources once considered irrevocably tied to ejido lands.[20] In San Lázaro, the local leadership decided to take matters into their own hands, and sell some of their water rights in order to generate capital required to refurbish wells on the floodplain. As discussed earlier, a previous bid to sell the 100,000 cubic meters/year extraction rights to a *maquiladora* in Nogales was hampered by the economic downturn after the terrorist attacks of September 11th, 2001 and rising costs for sending goods across the border. Yet, in the winter of 2002 and the summer of 2003, the ejido leadership negotiated the sale of these same rights to a local mining company--Peñoles S.A.—that the company would retire and use to substitute for water pumped from its gold mining operations in the Milpillas division of the ejido.

The profit from this sale will then be combined with one third of the capital supplied by the Ministry of Agriculture (SAGARPA) through *Alianza para el campo*, and another third supplied by the *municipio* of Santa Cruz to refurbish two wells on the floodplain.[21] The remaining water rights would then be exercised and extracted by the community, using the two wells (although neither will have sufficient capacity to extract 200,000 cubic meters/year that remained after the sale of rights to the Peñoles Corporation). A portion of these funds

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[20] Although reformers would argue that ejido water rights were already being developed, leased and sold illegally prior to the reform of Article 27 (e.g. Whiteford et al. 1998).

[21] As of May 2006, the ejido had purchased pumps for two out of three proposed locations. The first, "*la pompita*" was functioning properly and withdrawing an undisclosed quantity of water for irrigation on the floodplain. The second well, referred to as "martinez" had failed during the drilling process. Drillers were unable to find water in three separate passes along the floodplain. The third well location was not yet refurbished at this time. The concrete canal lining was not yet underway.

will also go into lining the *acequia madre* with concrete in order to decrease seepage and increase delivery. Wells will be electrified and water distributed to *parciantes*, depending upon contributions of labor, money and need. This tripartite cost-sharing arrangement characterizes the new rural investment policy of the Mexican government developed during the Zedillo presidency and carried on during the Fox administration. The not-so-subtle tautology of the impact of this policy on San Lázaro is that the ejido is forced to sell the very resource it needs to develop in order to raise capital needed to develop it!

At this point, without the functioning refurbished wells in place, I can only speculate as to the economic and environmental end results of the well development along the Santa Cruz. Although hydrogeologic conditions vary along the course of the Sonoran reach, the floodplain, filled with relatively shallow Holocene alluvium deposits will only support so much pumping before base flows on the gaining stream are affected, as they are in other reaches, such as 11 kilometers upstream in Santa Cruz River, and just 20 kilometers downstream near Ejido Cardenas Valdez. In both of these reaches, extensive pumping results in large drops in stream base flows during the dry seasons, converting the river between San Lázaro and the international border in particular, into an ephemeral stream.

We know that a highly transmissive alluvium characterizes the geology of the San Lázaro reach, meaning it absorbs precipitation or surface water easily, characterizes the river bottom. This layer-cake of rock, sand and water is also quite shallow, so rains quickly augment surface flows. Its shallowness also means that the subsurface water also be easily perforated or tapped by wells. Although the shallow aquifer (over a mile wide and 100 feet deep at Paredes) is easily tapped for subsurface flows, because surface flows are intimately linked to the subsurface flow of water in the alluvium then stream water levels will drop quickly. Overall, this results in a river that is highly sensitive to precipitation, drought, and groundwater pumping.

On the other hand, the refurbishment of the wells and the redevelopment of the floodplain agricultural zone are important to maintaining a viable economy in the community. Forage raised there could help to alleviate grazing pressure on the more degraded pastures, as it once did in the past. Furthermore, the cash crops that might be cultivated on the floodplain have potential augment ranching livelihoods already strained by neoliberal policies and economic shifts—particularly the slide in the price of beef cattle and calves (as I will discuss below). Or, as Sheridan (1996) hypothesized, it might lead to capital accumulation and concentration of land and water rights in a smaller number of hands than ever before. If water is not distributed evenly, or if a small number of *ejidatarios* manages to control that access, then we would predict this latter outcome. As of July 2003, only six *ejidatarios* actually regularly participated in the *acequia* maintenance and seasonal cultivation. A smaller number (5) were part of the negotiations with the *municipio*, the agricultural ministry, and the mining company for refurbishment project. Given this, Sheridan's outcome may indeed be on the horizon. Whether either of these scenarios, or some combination of them might arise, however, at this point is only educated speculation.

Non-governmental Gringos: The Sonoran Institute

As with many areas of Mexico and Latin America, another actor entered the area in recent times--a conservation-focused non-governmental organization (NGO). The organization has had a very important impact on the community's resilience and innovation despite the fact that it falls prey to some of the same pitfalls that critics have leveled at other NGOs operating in the developing world (e.g., Escobar 1998; Orlove 1996). I will use this section to describe the history of interactions between the NGO and San Lázaro, as well as dissect some of the outcomes and potential results that this new set of relationships has created.

In late summer of 1997, Joaquin Murrieta-Saldivar led a small group staffers from the Sonoran Institute (SI) on a trip up the Santa Cruz River into Mexico. The Tucson-based NGO focuses on "community conservation", a fluid phrase encompassing the values of information exchange, dialogue, and bottom-up collaboration that results in conservation of cultural and biological assets while supporting economic foundations (Sonoran Institute 2005a: 1). SI's geographic area of specialty included the intermountain west, the Southwest, and by extension, northwestern Mexico--particularly biologically rich areas bisected by the U.S.-Mexican border. For this reason, Murrieta-Saldivar and his coworkers found themselves exploring the oak-savannahs of the Upper Santa Cruz Watershed that late summer day in search of some "conservation opportunities". They first briefly passed through towns southeast of Nogales--Mascarenas, Buena Vista, and Santa Barbara. They drove slowly through San Lázaro, lingering over the plaza and the dusty streets but moved on to the *municipio's cabacera* (seat) of Santa Cruz. There they searched in vain for connections and retired to a local restaurant for a midday meal. While in the restaurant, their conversation attracted the interest of the *presidente municipal* dining in a neighboring table, who hastily started a dialogue with the non-governmental representatives. After that fortunate encounter, SI staff held three successive meetings with municipal officials, usually over some local *carne asada*, beans and tortillas. The results were not immediately obvious, as the *municipio* did not voice much concern for the Santa Cruz River--the focus for SI's interests. The former president of Ejido Miguel Hidalgo and active member of San Lázaro's current leadership attended each social meeting, and finally encouraged Joaquin and Mark Briggs (then SI's science specialist) to come over to San Lázaro.

When they finally spent some time in San Lázaro, both were immediately impressed with the condition of the community and the reach of the Santa Cruz as it flows through the ejido. Although it had obviously been grazed extensively, Briggs and Murrieta-Saldivar noted the large stands of cottonwoods and willows along the floodplain. The floodplain bordering the agricultural zone had only recently been cut by flooding events (in the mid-1980s), so geomorphic changes were not immediately irreversible. For his part, Joaquin revealed that he was most intrigued by the fact that people were friendly, that there was a neglected but still-standing community center on the plaza, that backyard gardens abounded, that ranching still seemed to be a way of life, and that the river's condition could be tied to local water needs--most obviously, irrigation water for the neglected agricultural zone, leveraging common interests in river restoration and economic livelihood. Joaquin also observed potential conflicts between ejido and private groundwater pumping, erosion in the uplands and bank cutting along the main channel of the Santa Cruz (Joaquin Murrieta-Saldivar, personal communication, March 2006).

Sonoran Institute began a series of five meetings with community members--again over *carne* and *cervezas*--to determine if the community could collectively define some goals that SI could contribute to. The goals that resulted from the meetings included improvements to the plaza and community center, better ranching conditions in the uplands, reduced dumping in the river, and more local livelihood strategies (ibid.). For it's part, SI defined its goal as "conserve and restore ecologically important areas of the international Santa Cruz River by addressing the impacts of a rapidly growing population and enhancing the working landscape tradition of rural communities" (Sonoran Institute 2005). SI saw San Lázaro as an anchor in the watershed for the organization that would allow them to move both up and downstream into the U.S. and Mexico. But the focus was always on the Santa Cruz River itself, or as Joaquin put it "to maintain functionality of the river while improving or preserving a working landscape." Functionality was defined by Murrieta-Saldivar in geomorphic and biological terms, while the working landscape equated to improving the viability of agropastoral livelihoods (personal communication, March 2006).

The organization embarked upon several projects in the community--though slowly at first and with careful deliberation so as not to ruin its chances of successful collaboration. Always the community or its leadership was asked what they would like to see accomplished. The first tentative project was helping the community to procure and paint trash bins to contain the waste that was inevitably drifting into the Santa Cruz or its tributaries through wind and water. As Joaquin put it, this first project was a small one but it built up trust between the partners (ibid.). Back in the U.S., staff at the Sonoran Institute expressed some impatience with the slow progress--though Murrieta-Salvidar and Briggs expressed confidence and urged the organization to think long-term.

Next, Ventura and the Institute selected one of the six cattle management groups to collaborate with. Ventura's own group--"*grupo cinco*" (group five) became their laboratory. Group five controls pastures in some of the most productive areas of the ejido--the high plateau country in the foothills of the Sierra Chivato where increased precipitation, lower evapotranspiration rates, and additional runoff from the high country surrounding it has created large expanses of grassland dotted by stands of oak, juniper, and pine. The area is known locally as Milpillas (little fields) and has been under management as a cattle pasture since the days of the Cananea Land and Cattle Company (which actually managed the lands separately from San Lázaro). The Sonoran Institute's first project with Group Five was fencing off a significant portion of the pasture so that cattle could be removed, and the area allowed to recover between periods of grazing. SI also created a grass seed bank to bring back certain species that had virtually disappeared from Milpillas in recent years. With more fencing, the group excluded cattle from a 1,400 hectare portion of the oak and juniper woodlands, with the goal of creating a wildlife management area or *unidad de manejo ambiental* (UMA) that will allow them to sell permits for private hunting within the boundaries of the UMA. As of this writing, however, this last strategy has not paid off since the Mexican environmental ministry (SEMARNAT) has still not approved their final certification (SI representative, personal communication February 2006).

SI has focused on watershed processes, seeking to stabilize stream entrenchment and increase upland infiltration rates. In the uplands, Group Five and the Institute constructed over 1,300 rock gabions between 2003 and 2005 (ibid.). If placed properly, these structures slow water in ephemeral streams, allowing some sediment capture while slowing down cutting, coupled with increased infiltration resulting in higher soil moisture upstream. Until 2004, Group Five was the first and only group to work with SI on range management issues. In that year, the NGO began a series of negotiations with members of Group Four, which manages a portion of the river bottom most impacted by stream entrenchment. In this reach, SI and Group Four have invested in 2 kilometers of exclusionary fencing and cattle drinkers that keep the animals from grazing along the river itself and that may allow the channel to reestablish a geomorphic stability. This project created the first reach of the Mexican Santa Cruz without direct riparian grazing impacts. A management plan for the area has not yet been completed as of writing this document but SI reports that this is priority for 2006 (Sonoran Institute 2005).

According to Joaquin, two of the most significant projects for the NGO and community were the reestablishment of a community center with its occupancy by a Mexican representative (Alfonso Gonzales Siquieros and his family) and the development of a middle school birding group--*Los Halcones* (ibid.). Once revived, the *Centro comunitario para la conservación del Rio Santa Cruz* (Community Center for the Conservation of the Santa Cruz

River) became a focal point for community meetings and visitors passing through San Lázaro. The author lived out of the *centro* while in the field and observed that the building and its occupants were critical to a variety of projects including meetings, storage for important documents, researchers, construction of environmental education displays, and grant writing.

Los Halcones (the falcons) is a group of middle school students recommended by their parents and teachers for intensive classes taught by Alfonso Gonzales, other Sonoran Institute staff, the U.S. National Park Service, and members of the Department of Scientific and Technological Investigation (*Departamento de Investigaciones Científicas y Tecnológicas de la Universidad de Sonora*--DICTUS) at the University of Sonora. *Los Halcones* conduct bird surveys, water quality testing, and other projects including frequent trips to the United States for exchanges with middle and elementary school youth. One young man received a significant scholarship to attend an international ornithology meeting in Monterrey, California. Some of the first and second generations of these students have gone on to secondary education with the intent to study at Universities--a rare occurrence for teens in the countryside.

The Sonoran Institute has written that it will "continue to work collaboratively with partners in the U.S. and in Mexico to ensure this important waterway continues to support vital ecological and cultural resources" (Sonoran Institute 2005). According to its website, the NGO aims to publish the results of three years of bird surveys and community outreach by *Los Halcones*, finish the management plan for the two-kilometer riparian restoration corridor along the Santa Cruz River in San Lázaro, increase capacity for the established community-based organization to sustain the operations of the San Lázaro Community Conservation Center in the long term, develop a bi-national and multicultural ecotourism destination with La Ruta de Sonora Ecotourism Association[22] and lastly create a conservation corridor along the Santa Cruz River of connected and conserved lands (ibid.).

The Sonoran Institute, like conservation-oriented NGOs operating in the rest of Mexico and Latin America, faces a number of obstacles to effectiveness. Namely, these include issues with measuring success, developing or maintaining community participation, and abiding suspicion among clientele, the Mexican government, and other actors in the watershed. Furthermore, there are serious critiques to be leveled at a U.S.-based NGO operating in Mexico, even if its primary contacts with the community are Mexican or Mexican-American. These more academic critiques will be addressed after I discuss the obvious issues of performance from the perspective of the organization and community collaborators.[23]

The first major problem with the San Lázaro project is a lack of wider participation by more community members. Projects involving groups four and five, environmental education involving *los Halcones,* and a few other less significant projects constitute the sum

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[22] La Ruta is another project created by the Sonoran Institute to generate ecotourism throughout Southern Arizona and Northwestern Mexico. La Ruta has been especially successful in fill tours to Cienega Santa Clara in the Colorado River Delta. It has so far not been successful in creating the same opportunities for the Upper Santa Cruz because of the poor roads to the area.

[23] In the interest of scientific transparency, it should be noted here that the author was in the position of directly benefiting from the Sonoran Institute while in the field. The organization provided me with contacts through its local representative, a place to stay, and even sporadic funding for small field-related expenses. I also worked for SI in 1999 and 2000 as a consultant, which first brought the Upper Santa Cruz Watershed and

of the work in the Mexican reach of the Upper Santa Cruz Watershed. SI or its local representative bears some responsibility for this, but more pernicious issues undercut the organization's abilities to gain buy-in. In its approach to the community, the NGO requires some kind of match for funding secured and the easiest form is community labor. Often Institute projects lack participation because they are perceived as less economically remunerative activities than others already available to community members. As Murrieta-Saldivar put it: "they just don't want to make the money or do the improvements [such as gabion construction] when they have other means to a quick financial gain" (Joaquin Murrieta-Saldivar, personal communication, March 2006). This latter issue is treated at length in Chapter Seven. On the other hand, out of necessity SI has allied itself with key community members--such as the former ejido president--who have yielded access to specific groups. Since the community is not homogenous, this has meant some individuals, households or groups have refused to become involved with SI's activities because of who it associates with. Intra-household frictions and community fractionalization have inevitably closed some doors for the organization. Obviously, this too has reduced participation by some in the organization's projects.

The lack of engagement between a significant number of rancher-farmers and SI reveals that the organization can only go so far in reaching out to the community and that the community is not always sufficiently organized to engage the NGO's offers for help. For example, the fact that two out of six cattle management groups working with SI is

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San Lázaro to my attention. Furthermore, most of my contacts within SI are personal friends and emblematic of the level of communal participation in land management decision-making that the remaining groups can create. Some groups are less effective than others noted a former ejido president (personal communication, June 2003). As another leader put it: "*No se porque exactamente, pero seguro que hay gente que no cuidan a sus animales ni terrenos*" I don't know why exactly, but I'm sure that there are people who don't care for their animals nor their lands (personal communication, September 2002). As discussed earlier, the high number of absentee landowners has also contributed to disorganized groups with little local decision-making and inconsistently attended meetings. Groups four and five are in fact among the best-organized groups--although group five significantly more so than those participating in the riparian area exclusion project.

The Sonoran Institute, like many organizations or researchers working in academic and applied conservation biology face the fundamental issue of measuring success, particularly given the spatial and temporal heterogeneity of semi-desert grasslands within the greater southwest of North America. For SI, they define their primary metrics in San Lázaro as increased calving rates for rancher-farmers, diminished erosion, and increased vegetative cover (Murrieta-Saldivar, personal communication, March 2003). Calving rates are the easiest measure to apply, although these can only be applied in the context of the Milpillas pastures (Group Five). Diminished erosion and vegetative cover are more difficult, especially given the issues of highly variable precipitation and excessively varied soil types, slope and land use. In the later case, there is virtually no soils data for the ejido, and slope

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professionally important.

maps can generally only be produced with a digital elevation model that would be provided by the Mexican government (*Instituto Nacional de Estadística, Geografía e Informática*--INEGI). National data sets like Digital Elevation Models are rarely—if ever—provided to U.S. or European-based organizations because the data is considered sensitive "national patrimony" by INEGI. According to Joaquin Murrieta-Saldivar, vegetative cover is measured by photopoint monitoring, providing a time-series of each area. While this is usually an effective means to observing changes in vegetation over time, it does not indicate how the changes were produced and must be carefully correlated with climate and land use data that are not necessarily available for San Lázaro, although proxies can be generated (see Chapter Two). The debate over what conclusions can be drawn from photopoint monitoring continues unabated for research conducted in more carefully scrutinized U.S.-portions of the watershed (cf., Bahre 1991; Cook and Reeves 1976; Hastings and Turner 1965). Furthermore, time scales of change in the watershed are obviously far longer than the period of five years observed through SI's efforts. Is it therefore possible to even capture the appropriate data to record "improvements" or "declines" in riparian areas and rangelands?

Outside of these operational issues, conservation and conservation biology as an applied discipline has not escaped perhaps appropriate academic scrutiny (Escobar 1998; Milton 1996; Scoones 1999). So too is criticism applied to NGOs as a social phenomena of development and environment (Escobar 1995; Ferguson 1990; Fisher 1997). In fact, the major issue that social sciences have with both sets of practices is that neither has been adequately unpacked of its ideological baggage or assumptions. The implication is that

NGOs are doing a good thing because they are by their nature apolitical and uncapitalistic (Fisher 1997:442). Some analyses take the position that NGOs such as the Sonoran Institute are "antipolitical" in nature (Ferguson 1990: 6) in that power relationships are obscured within their practices (Fisher 1997: 446). Thus, just as the environmental movement is generally depoliticized by an emphasis on the production of policy by objective scientific method, so too are the bearers of its wisdom at a local level (Jasanoff 1990: 18). Likewise, the local level or San Lázaro becomes the site of "problems" that are hence generated there and can be "fixed" through local action in concert with the NGO, rather than structurally produced (i.e. political ecologic). Hence, the Sonoran Institute is in the position to solve these local problems--even when defined by the organization as "collaboratively"--while the community is seen as less than empowered. Furthermore in this analysis, San Lázaro is divorced of its wider political economic nexus, meaning that wider structural issues like drug cartels, neoliberal policies, and even climate change cannot be adequately addressed by either the NGO or the community.

Despite the criticisms, the ejido's resiliency has been influenced (perhaps positively) by the presence of SI. While the government funding has drained from the countryside in the past decade, SI stepped in to provide some matching funds for innovative projects like gabion construction, seed banks, and UMA creation. The grant-writing skills of their local representative also provided a much-needed boost to local abilities to secure other sources of funding for community projects. SI claims (with good reason), that the activities of *Los Halcones* have had a significant impact on household knowledge of local biodiversity. One could characterize SI's efforts as diversifying the economic portfolio of a few members of the community, while making others aware of the options available—although the entry of narcotics trafficking has made this nearly an impossible conversion for most. Yet at a point when the community was clearly undergoing a period of "creative destruction" at the end of collective management, the NGO has acted to increase the level of local innovation in the adaptive cycle—much like a chemical catalyst rather than as an active participant itself.

The Adaptive Cycle and Neoliberalism

The period of rapid social and ecological change that occurred during the 1980s and 1990s can be explained by the heuristic tool of the adaptive cycle as described by Holling (2001) and Walker et al., (2006). The cycle is again presented below for reference.

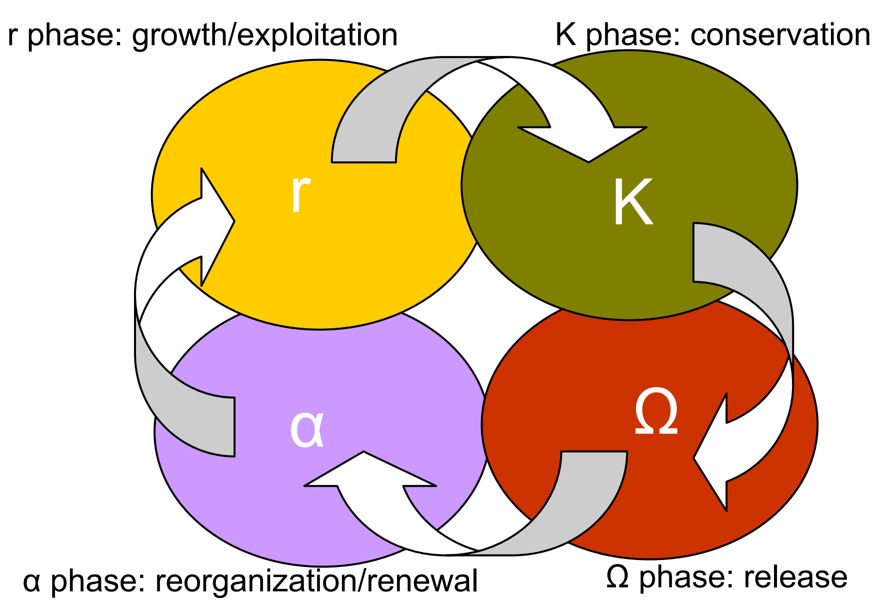


Figure 6.7. The adaptive cycle. Source: http://www.resalliance.org/570.php

The adaptive cycle moves through two major transitions. The first or "foreloop" from r to K is characterized by slow, incremental growth, increasing complexity, and accumulation in specific pockets. Where r is characterized by rapid colonization of a frontier or disturbed site, the movement towards a stable system is slow and incremental as complexity increases and inputs are stored or even concentrated in environmental sinks. In the case study of San Lázaro (or rather, Ejido Miguel Hidalgo), this is the colonization of the environment by the *ejidatarios* and then the colonization and exploitation of the economic environment by the bureaucrats and bank officials who exploited the ejido's capabilities to extract natural capital and convert it into financial capital (through cattle ranching and farming). This also took place by extraction of interest on loans addressed in more detail in Chapter Five.

The second "backloop" that moves from Ω to α is a much faster process of systemic collapse and reorganization. The rapid release of system elements—stored inputs but also systemic components as entropy dominates—allows for innovation. This innovation creates a sort of "re-colonization" of the disturbed system, leading back into the foreloop (r to K). The economist Schumpeter (1950) noted that societies (or rather economies) often went through a period of creative destruction once the system becomes increasingly fragile, over-connected, and vulnerable to sudden release. This characterizes the omega (Ω) phase. Destruction, however, cannot be a permanent condition; opportunistic agents (species, firms, social movements, or individuals) move into the vacuum and reorganize the now released inputs so that they become available for the growth-exploitation (r) phase. This reorganization phase is designated the alpha (α) phase (Holling and Gunderson 2002: 35). One of the key messages of this model is that capital (resources or inputs) is harnessed in differential fashion throughout the cycle—and move from potential to practical as the agents in the system seek new opportunities or conserve existing resources. In the case of Miguel Hidalgo, the ejido's slow accumulation of resources fell off in the 1990s with the reorganization of the ejido and resulted in a set of new opportunities for outsiders to move in and "colonize" the social and ecological landscape. These included ranchers from Santa Cruz, businessmen from other parts of the state who purchased agricultural lands on the floodplain, and even the North American NGO, the Sonoran Institute which, even with good intentions, took advantage of the withdrawal of government from the countryside. In Chapter Seven, I will add another colonizing actor to the mix: narcoelites.

CHAPTER SEVEN: THE NARCOECONOMY AND THE NEW ELITES

On a warm spring night, around 5:30 a.m., Jose Ramos, 21 of San Lázaro, was found sleeping in old travel trailer outside of Patagonia, Arizona. His backpack was filled with about 10 kilos of marijuana and 4 kilos of cocaine that he has spent the night carrying from the border to this point. Here he was to rest and wait for another burrero to come by in a pickup truck and collect the drugs, transporting them on to another point in Arizona. The Border Patrol agents who discovered him-based on a tip--did not encounter any resistance from the young man as he was apprehended, cuffed and placed in the back of the vehicle. He was transported from Patagonia to Tucson 40 miles away where he was arraigned on charges of drug trafficking. Jose was then transported to Florence, Arizona, where he was incarcerated for 3 years for this crime. He would be released and returned to Mexico in a little over 8 months during the following winter after the cattle sales and before the small spring alfalfa planting that takes place every year on the floodplains west of town. Back in San Lázaro, his newly married bride Mariana was distraught when the news arrived through a family friend in Tucson. Their son was just two months old at the time. Mariana had no source of income other than selling enchiladas after church services. Other family members stepped in to help the young mother cope. His brother, the mayordomo of the cattle operations in the town, had relied upon Jose for some of the more important tasks during the busy fall months. Jose was one of the best baseball players in the local team. His teammates were disappointed and saddened by his arrest.

The border region in which San Lázaro sits is undergoing a transformation from agrarian to industrial. It is also experiencing of a fundamental shift from centralized to internationalized governance and from emphasis on overt economy to a reliance on covert economies, tied to the trafficking of labor and drugs across the border into the United States. San Lázaro, like thousands of other communities along the border is experiencing the outfall of these shifts in political economy. Of particular importance to smallholders are the economics of smuggling as this has engendered major impacts on the expectations and livelihood choices for the next generation of community members. Unfortunately, their embrace of a *narcoeconomy* has invited a new set of elites into the community, replacing the Mexican federal government, and international capitalists such as William Colonel Greene.

I will discuss one aspect of the *narcoeconomy*--drug transshipment--from the perspective of individuals, households, and communities. In doing so, I will take a case-study approach and attempt to examine the economic, ecological, political and cultural logics behind why individuals, households and communities participate in the business. Why do people engage in such a risky behavior? What drives someone to become a *burrero* or mule for the drug cartels? What are the repercussions of this activity for household and community livelihood security? How do we examine this phenomenon free of the heavy morality play of the modern policy-making discourse?

To tackle these questions, I believe it is critical to look at the precursors for smuggling and understand it within an economic logic that often drives household decision-making processes. We must remember that households are foremost groupings of people with common interests-the hearth is more than just a source of warmth and tradition; it is also the distribution point for wealth. Recent changes in Mexico's political economy have led to the development of a powerful "narcoeconomy," based on the production, distribution, and consumption of narcotics. Ideologically driven development strategies based on neoliberal models have stripped small-scale agricultural producers of important tools and led to widespread transformations in ownership and commodity production. In rural areas along the U.S.-Mexico border, these changes-coupled with environmental transformations-have driven some households to restrict or abandon agricultural livelihoods in favor of adopting riskier, more lucrative trafficking activities as part of their livelihood strategies. Environmentally, the agriculturalists in the community have faced degradation of soils and rangelands, diminishment of water resources, and a multi-year drought.

So producers and their households have sought other off-farm livelihood strategies to sustain and reproduce themselves. However, like legal, off-farm labor elsewhere in Mexico, I argue that householders are adopting trafficking as just one more strategy to supplement a struggling subsistence agricultural economy. This creates tensions within the households as risk is perceived and absorbed by different members in different proportions. Household tradition and authority often support economic arrangements, leading to intense conflict when household members strike out to form new arrangements and gain new power within the established order of the family.

***El negocio*: the rise of the narcoeconomy in Mexico and Sonora**

The business of narcotics production and smuggling has a relatively long history in Northwestern Mexico and Sonora in particular. This vast, largely arid region with great distances between settlements and official border crossings is an ideal area for production and smuggling. While the historical geography of narcotics in Sonora is relatively long, the development of *el negocio* into the industry that influences local livelihoods and social structures in San Lázaro is a phenomenon of the last three decades. In this case study, smuggling is by far more important than production, for both ecological reasons-it is too cool and dry for marijuana-and geography-the community's strategic position in the hinterlands of the border makes ferrying drugs lucrative and easier than heavily policed urban zones. To summarize, production, though present is not as lucrative and facile as smuggling.

Opium poppies have a particularly long history in the state, brought to the Americas by Chinese immigrants in the mid-19th century. Farmers grew small plots of the poppies and then traded the gum within the Chinese and East Asian communities of the region (Astorga 2003). The Chinese were later expelled into neighboring states-mostly the United States-in a fit of xenophobic rage by European-origin Sonorans. While the Chinese diaspora resulted in a loss of many cultural traditions to Sonora, opium production continued on a small scale in isolated locations such as Caborca, Pitiquito, and Cananea (Astorga 2003). But opium production in Sonora has never moved beyond the small-scale producer for local consumption. Rather, familial and social linkages with China and other locations in East Asia allowed individuals to move the drug from ports in Sonora or Sinaloa into the United States where the market for narcotics flourished during the years of American alcohol prohibition.

Marijuana production also came to Sonora with immigrants from Asia. Like opium poppies, marijuana production was scattered throughout the country and largely localized (Astorga 2003). From the 1970s onward, however Mexico became the leading supplier to U.S. markets (Carpenter 2003: 14). When the U.S. government began spraying paraquat on to Colombian fields, Mexican producers and smugglers saw increased U.S. demand as consumers sought to avoid the potential for poisoning by the chemical. By the beginning of the 1980s, Mexico supplied over 75 percent of the U.S. market for marijuana (Ruiz-Cabanas 1996: 21). Mexican producers, concentrated along the west coast of the country and particularly in the state of Sinaloa, ramped up production as well as smuggling operations. In doing so, the early leaders of these operations cemented into place the beginnings of a cartel that would later control most of lucrative U.S.-bound cocaine smuggling business by the end of the 1990s. To this day, Sinaloa remains the epicenter for much of the production and related activities in *el negocio*.

Smuggling, however, is the more lucrative of the two businesses. The production end of the commodity chain yields little profit, while adding value to the crop by exporting it into more highly controlled markets-such as the United States-creates large profits for the drug cartels and others involved in *el negocio* (Toro 1998). The reasons for the more handsome profit are logical. First, the networks for distribution of the drugs and repatriation of profits are highly controlled in the U.S., meaning that risks to traffickers are far higher. From 1981 on, the United States government has spent billions in drug interdiction efforts, reaching by 2000 over $50 billion a year in the war on drugs (Carpenter 2003). Second, the mark up on the drugs, once they cross into the U.S. (owing of course to the risks involved) yields an enormous profit. For example a kilo of cocaine might fetch $5,000 in its native Colombia but once it crosses the U.S.-Mexican border the average street value of that same kilo is US$20,000. While the risks obviously drive this price jump, the "costs of doing business" as well as the inequalities in economics between Latin America and its rich neighbor also yield bigger payoffs for smuggling. This is an example of the "balloon effect" where source control increases the value of the commodity which then counteracts the increased risks associated with production and smuggling (Andreas 2000: 16).

Mexico does not operate in a vacuum with regards to the drug production and trafficking business. The international context was critical to the formation and evolution of Mexican drug cartels that have become among the most powerful in the world. Specifically, the suppression of trafficking in Cocaine from Colombia and the Andean region resulted in routes through Central America and Mexico. Successes in suppressing opium and heroin production or trafficking from Southern Asia and Turkey resulted in the explosion of a new industry across much of northern Mexico. Actions of Mexico's northern neighbor have driven most of these changes and opportunities for new cartels.

Cocaine, in particular, became more lucrative for Mexico when between 1989 and 1992, the United States cracked down on the financial institutions that controlled the Colombian cartel's profits. The cartel shifted to paying Mexican traffickers-then of growing importance for transport since the DEA had largely shut down Caribbean routes-in cocaine itself, rather than dollars or pesos. Mexican drug traffickers could then resell their payments into domestic and U.S. markets, giving these traffickers a substantial stake in U.S. wholesale and retail markets. They moved rapidly to solidify that stake by creating or expanding syndicates of their own. By the late 1990s, Mexican cartels controlled upwards of 70 percent of the U.S. market for cocaine-now functioning as the major vehicle for Colombian or other Andean-region cartels (Riley 1996: 38).

The late 1980s and 1990s were truly formative years for the Mexican cartels, a period when they began building an infrastructure of official corruption and market share that now dwarfs most cartels in the world. Because of their strategic location and ability to smuggle the products-hence adding value to them by assuming the risks-the Mexican cartels have amassed significantly larger power than even their Colombian counterparts. Mexican cartels' trafficking efforts have resulted in the modern version of *el negocio*-well connected through the highest orders of government corruption, ruthlessly organized for success, and most importantly, threaded deeply into the Mexican economy. In fact, "the business" is perhaps the most honest term for the phenomenon, at least according to Foreign Minister Jorge Castaneda, who bluntly admitted, "It's a business. It has to be seen as a business. And there are regions of the country where he drug economy really is central to the local economy." In zones of production and smuggling, the economics of drugs can, through its macroeconomic weight and strategic influence, transform the national or local government into a "narco-state." By 1994, Mexico's cocaine cartels were paying bribes totaling $460 million, more than the attorney general's annual budget and were grossing $30 billion, four times the value of the countries oil exports (Andreas 2000: 6).

Prohibition has contributed to the growth of drug trafficking as one of the world's largest (and fastest growing) industries (Andreas 2000). Over the past 30 years, the U.S. war on drugs has simply served to push production, processing, and smuggling of illicit drugs back and forth across the globe's three critical trafficking regions-between Turkey and Laos in the Asian opium zone, from Bolivia to Colombia in the Andes coca belt, and from southern Florida to northern Mexico along the U.S. border. At each turn in these many shifts, consumption, production, and corruption have ratcheted upward especially in the case of northern Mexico (McCoy 2004: 24f). In some cities along the border such as Juarez and Tijuana, the cartels exercise such control that locals, the DEA or other U.S. agencies, cannot trust police, courts and officials in local government. For over 10 years, the deaths of myriad people (many women) in the poor slums surrounding Juarez attest to the power of the cartels and the inefficacy of seemingly corrupted local or federal police units to bring the perpetrators to justice (Staudt and Coronado 2002: *passim*).

This omnipresent corruption has lead many observers of the drug war to reflect that Mexico is undergoing a transformation similar to that of Colombia over two decades ago-into extreme violence and pervasive official corruption. They speak of this as the "Colombianization" of Mexico by the cartels, narco-economics and domestic or international interdiction efforts. Literature demonstrates that it is the illegality of the product, not the drug itself, which leads to this corruption (Tullis 1995: 5). Like Colombia in the 1980s, the last decade in Mexico has seen a tremendous increase in official corruption, building up to the assignations of party boss Jose Francisco Ruiz Massieu and presidential candidates-the latter especially significant in that the hit on PRI presidential candidate Luis

Donaldo Colosio took place in the cradle of the most important cartel-Tijuana (Carpenter 2003). As of February 2005, the U.S. State Department is now warning Americans to exercise extreme caution in northern Mexico as rival drug cartels fight to establish a new equilibrium. Violence between rivals battling for control of the lucrative Arizona-Sonora corridor increased dramatically in December, January, and February of 2005 (Marizco 2005a). Sonoran's-through both official and unofficial channels-however, are trying to preserve an important sense of security for American tourists who, they argue should continue to cross the border and spend dollars in one of Mexico's richest states.

The discourse surrounding the "Colombianization" or increasing violence is largely irrelevant to the fact that drug production and transshipment in northwestern Mexico has increased significantly in the past 30 years. The DEA itself cannot speculate as to whether a peak or plateau has been reached since records reflect only successful interdiction efforts. Figure 7.1, below, illustrates the total amount of narcotics (in pounds) seized in this region of the U.S.-Mexican border since 2001 (Marizco 2005b). What this means for San Lázaro is the creation of powerfully attractive economics at the local and regional-scale that, given the instability and dubious viability of traditional agricultural pursuits. For the young and more risk-accepting members of the community, smuggling is an attractive option to years of hard labor without easy-or even certain-rewards. As described in the previous section, the difficulty of agriculture in the community is both political economic and most importantly environmentally driven.

Year	Marijuana	Cocaine	Heroin	Methamphetamine
2004	990,100	10,016	146	2,461
2003	917,042	6,476	16	1,683
2002	517,987	7,487	15	609

Table 7.1. Types and quantity of drugs apprehended in smuggling operations in the Tucson sector (between Douglas and Sasabe, Arizona). Source: Marizco 2005b.

La burriada: The Commodity Chain in Border towns

When the drug cartels were pressured by new, high-intensity border policing in California and Baja California (Andreas 2000: 66), the Arizona-Sonoran border became an attractive area for operations. It was attractive both to the drug cartels (i.e., the so-called balloon effect) and to members of struggling ejido households. Small towns in cross-border drainages-already natural travel corridors for migrants and wildlife alike-like San Lázaro as well as the vast Tohono O'odham reservation to the west-rapidly became new corridors for smuggling of drugs into the United States (Perramond 2004: 216). By the late 1980s, increased enforcement in South Florida and elsewhere along the Caribbean, Gulf and Atlantic coasts had pushed smuggling operations into the deserts of the Southwest, especially the area along the California border. Furthermore, the U.S. government's enforcement pressure in the southeastern U.S. created strong linkages between Mexican and South American organizations since the latter could no longer get their products into the

U.S. on their own via air and sea routes to drop sites like Florida.

While it is impossible for me to give even rough dates for when the drug trade became significant for members of the community, the fact remains that by the mid-1990s, faced with a deteriorating political economy, the members of the community looked to other livelihood strategies to make up the difference. This period was confluent with the period of intensified use of trafficking routes in Southern Arizona and particularly southeastern Arizona-a region typified by rugged terrain, little infrastructure and poor law enforcement presence along both sides of the border. In fact, while other areas of central and western Sonora were served by blacktop highways by the late 1980s, the region between Nogales, Sonora and Janos, Chihuahua is largely unpaved outside of the larger towns. Today, the road that runs from Nogales to the municipal capital of Santa Cruz and into the San Rafael Valley (Arizona) is still one of the roughest roads in the region. For a local with intimate familiarity with the terrain, trafficking would be easy money.

The easiest way for becoming involved was to guide the traffickers themselves, many of whom at first did not come from the community or even from Sonora-although some may have had family-connections. Rather, with west coast organizations largely dominated by Sinaloans, the Sonorans had an instant comparative advantage that they could exploit in service to these more southerly-based organizations (Loret de Mola 2001). Even the Tijuana cartel could not manage to control sufficient resources in a region with the hottest and sometimes coldest temperature extremes. So a local teenager with a horse and a natural familiarity with the *sierra* can easily insert himself into the global narcotics commodity chain.

Little of this activity is known beyond the stories of those who failed at their tasks.

Stories collected by the author included a truckload of marijuana that was unsuccessfully transported to the border from the vicinity of the town, but when intercepted by U.S. Border Patrol Agents, the driver and passenger fled on foot. Truck trafficking is in fact much more common now that larger loads are brought across the border. Vehicles are typically stolen from U.S. cities, stripped down and even armored. The rigs are then driven across the border by a pair of drivers and flanked by another vehicle. If either driver is successful, the materials lost are considered part of "the cost of doing business." Truck traffic has increased in the San Rafael Valley, according to locals, an Arizona State Park that shares the border, and media sources. Unfortunately, the Bureau of Customs and Border Protection (BCBP) currently will not publish statistics related to interdiction efforts anywhere along the border, citing national security concerns (BCBP).

Another way that locals can insert themselves into the global commodity chain is by storing shipments before they are transported across the border. In some cases, this may take a matter of hours to a matter of weeks, depending upon the logistics of trafficking during the period in question. Far-flung ranchos (satellite communities) serve this purpose well, since local or even national law enforcement often do not have easy access to these remote outposts. If shipments are moved between storage points, they may be incorporated into local shipments of goods, produce, livestock or other commodities. These ranchos may serve as drop sites for the drugs as they are moved from point to point in the organized cat and mouse of border policing and evasion by the cartels. For example, ranchos and other communities may receive different shipments or "pacas de kilo" that are then moved back and forth as lieutenants in charge of pushing the drugs across the border make final decisions about the ultimate route and method for movement. Communities hence take on similar roles to distribution centers in a global department store chain-in exchange for receiving, storing, packaging or repackaging and loading the goods, a small segment of the community benefits.

The distribution of benefits is never equal in the case of narcotics trafficking. Successful participants in the *burreada* of the commodity chain will often take home upwards of US$1,500 for a night's work, plus some drugs for their own direct consumption or sale to local markets. Households benefit with the instant influx of cash, which is often spent quickly on big-ticket items such as appliances, home-improvement projects, furniture, vehicles or livestock. In some cases proceeds from a successful foray may be distributed across families, although this often brings out social tensions between younger family members who accept *el negocio* as legitimate and older members who see it as a threat.

These social tensions and unequal patterns of benefit are also typified in the architecture of the community. The majority of homes in San Lázaro are small, 1-2 bedroom houses constructed of adobe, brick, or cement blocks during the 20th century. On the road entering town, however, are a half-dozen large homes, constructed in the last 10 years, some in the last 5 or less. These multistoried homes come with gates, hefty, glass-shard-topped solar walls and paved driveways. Their construction has generated jobs in the community for a new class of *jornaleros* (day laborers) who ply a number of skilled or semi-skilled trades.

While the construction of new homes is nothing new in San Lázaro or other border towns as they grow and change, the appearance of significantly wealthier homes is also an indicator of economic differentiation and change in the formerly egalitarian community.

Community members, however, will never speculate publicly-or at least not with a gringo ethnographer-about where the wealth for such construction projects originated. The generation-stratified social tensions do appear when I noted these new homes to some of the older members of the community and their response expressed disdain and sadness for the families living within them. One said "*que triste que viven aparte a la comunidad*"--how sad that they live so apart from the community (personal communication, September 2003).

El negocio contra la vida vaquera

The older generation in San Lázaro expressed guarded ambivalence about *el negocio* in the community. The case of C. and R. is a good case study in this-perhaps uncomfortable-relationship between the older generations holding on to their remaining roles in the post-revolutionary agricultural community (the remains of the ejido) and the young who have adapted to the new world dominated by the *narcotraficantes* and their ilk. R. was nearly arrested for his involvement in a truckload operation in a neighboring valley. He lives with his father-in-law C. in San Lázaro. C. frowns upon R.'s participation in this enterprise, though the satellite dish and clothes washer that R. purchased have smoothed relations. Neither discusses their tensions with each other but remain recalcitrant in their positions-one that openly embraces the narco-economy and the other who sees it as a drag on the agricultural revolution that created the ejido in the 1950s.

The downside of any of these activities is the distribution of real transaction costs across the commodity chain. Transaction costs include the danger of long trips through the mountains and deserts, time away from families and household or community duties, and social tensions within households and communities. These costs, however, are far outweighed by the impact of interdiction efforts on communities and households at the bottom end of the chain. As recounted in the vignette at the start of this paper, costs fall disproportionately on those who are apprehended brining drugs across the border, rather than those who give the orders in Sinaloa or elsewhere. The results should also already be familiar to the reader: a) long periods of jail time for the offender; b) extreme emotional trauma on the household in Mexico-especially given the inability for information to flow freely across the border, leaving families in the dark for long periods; c) the loss of money paid to the *burrero*; and d) a large opportunity cost as those incarcerated are unable to generate or contribute income to their households. A less direct but nonetheless important cost is placed upon the community as news of the incarceration returns to them-psychological stress, sadness and the loss of yet another member to the drug war.

The most disturbing consequence for those participating in *el negocio* is the addiction that often accompanies it. In the 1990s, *burreros* were paid in cash for their efforts. By the turn of the century, they were paid partly in cash and partly in kind with a small portion of the drugs themselves (Loret de Mola 2001). While stimulants like cocaine or methamphetamines were used to fortify those working through the night to move the drugs quickly, *nacrotraficantes* were not often given quantities of drugs for their own use until quite recently. The result has been the appearance of the slang term *périco* or parrot among locals. This largely urban term is meant to signify someone who snorts drugs-mainly cocaine-leading to a red, swollen "beak" of a nose. The spread of cocaine use in the community has become "an epidemic" in the words of one *ejidatario*. Local sales of narcotics-and the development of a considerable domestic market along the border are a second trend of import. The nearby city of Nogales, Sonora has developed such a problem with heroine and cocaine use that authorities and non-profit organizations have rushed to set up new clinics to deal with the new population of addicts.

In San Lázaro, the *perícos* have come home to roost. Community members complained that local kids were getting involved in consuming drugs as early as 1995, when a car with three 16-19 year olds careened off of a hazardous mountain road due—as one community member recalls—"*drugas y alcohol, ay pobrecitos*," drugs and alcohol, oh poor little ones (personal communication July 2003). Community members also complained about *perícos* hanging out on the normally quiet plaza late at night with loud music. Often, these consumers were referred to even more indirectly as *pajáros rocos* or noisy birds. And in 2002, while I was in the midst of my fieldwork, the 30 year-old leader of the local irrigation society, or *juez de agua* was found dead in his home of a cocaine-induced heart attack while his wife and child were visiting friends in the United States. The funeral ceremony was punctuated with a community leader's quiet invective on how "*drogas sería locas matantes*" (drugs can be crazy murderers). The injection of a domestic drug trade into the town created a lingering tension between purveyors of the commodity and those who feared its consumption. Whether or not members or entire sectors of the community benefited from the trade, families clearly feared the personalized use of them at home.

Lastly, however, are the consequences for the local environment in which the narcoeconomy is embedded. The influx of cash and commodities has freed some of the pressure upon rancher-farmers to produce in an increasingly risky environment. As the nine-year drought wore on and drove farmers out of business for lack of irrigation water and ranchers from the trade for lack of forage, the narcoeconomy afforded a risky but profitable alternative. That alternative has removed pressure on the community's rangelands-although new entrepreneurs from neighboring Santa Cruz have moved in to take advantage of cheaply leased, but poor rangeland. Much of this shift in land-tenure is not necessarily a result of the illegal economy but of the vagaries of the legal (and international) one. As I alluded earlier, land concentration has increased despite the poor conditions of the range and the fallout from President Salinas' neoliberal restructuring of the ejido land tenure system. So, even where environmental pressure is relieved by the alternative economy afforded participants, it does not guarantee that locals won't cede range and crop land to other parties-such as entrepreneurs from Santa Cruz, Nogales, or Hermosillo.

The narcoeconomy, however, has bolstered the off-farm sector to an extent that is difficult to measure. The community has been infused with ready cash in the hands of local narcoelites who spend it in a variety of ways. While construction costs have increased dramatically in Mexico due to migration to the U.S. (MacDonald 2005: 121), those who ply various construction trades in San Lázaro may make an adequate living from the construction boom itself. An average multi-story, middle-class house in Mexico may cost upwards of US$85,000 to US$100,000. Some of the more ostentatious homes in San Lázaro might employ a dozen tradesmen and cost upwards of US$250,000. This is all the more impressive given that most homes are paid for in cash without the benefit of construction loans. Fiestas, rodeos, and other leisure-related activities also increase with the influx of ready cash. These activities generate employment and entrepreneurial opportunities that generate off farm livelihoods. A local deejay in the community may make upwards of US$250 in a night—a large sum compared to the slow, often risky gains from the livelihood generated by largely moribund cattle ranching. While indirect, these construction and service sector jobs mean fewer people on the ranches and farmland of the community. The absorption of these potentially unemployed or impoverished ranchers into a greater economy designed to cater to the narcoelites is perhaps a mixed blessing.

Humanizing the Narcoeconomy

Does it pay off? Can *campesinos* make a good trade between the devil of the *narcotraficante* and the deep blue sea of a collapsing agricultural economy aggravated by extreme environmental variability? How can we humanize the discourse without becoming apologists for the either side of the story? Narcotics trafficking is an alternative avenue of upward mobility for entrepreneurial but marginalized social groups (Andreas 2000: 19), especially *campesinos* who have little access to legitimate business opportunities, even though they sit in a strategic position with regards to cattle production and U.S. feeder-calf markets just across the border. Narcotics trafficking has at least partially replaced the ranching because it allows instant integration into the global economy (though clandestine) that they had previously been shut out of by neoliberal forces at home and abroad.

The other side of the story, however is that as a part of Mexico's growing rural poor, the residents of San Lázaro are taking a step into a brave new globalized future that pulls them away from their marginalized but traditional role in the Mexican economy. The tensions between tradition—with concurrent poverty—and a sort of narcotics-induced upward mobility (MacDonald 2005: 116f) has created an interesting divergence from the agrarian trajectory of the ejido. An ironic parallel can be found within Daniel Nugent's (1993) study of Namiquipa, Chihuahua. The community, Nugent argued, is an example of the local-level social and political impacts of a revolution hijacked by elites at local, regional and national levels. In San Lázaro, we have a cutting-edge example of a post-revolutionary agricultural utopia that was first to be privatized, put through a brutal period of competition within regional, national and international markets, and then failed. Its agricultural economy in shambles, San Lázaro has now been hijacked by local, regional and national level elites of a different, criminal sort. Instead of the *ejidatarios* being characterized as spent cartridges of the Revolution, they might better be characterized as drug-addicted veteran revolutionaries, participating both reluctantly and wholeheartedly in a new world order of covert economic globalization.

Is the Narcoeconomy Adaptive?

An alternate view of the drug trafficking and accompanying economic transformation of San Lázaro is to see the narcoelites as part of a broader colonization of the community by the aggressive r-strategists. Narcoelites and their ilk have long been highly adaptive and able to exploit the weaknesses of their base countries (such as Mexico) and market nations (such as the United States). Moving into the frontier was a response to the shut down of other drug trade routes into the market. San Lázaro, an economically poor but strategically well-placed community served just the right combination to these elites.

Returning to the adaptive cycle and the concept of resilience, the advent of the narcoeconomy in San Lázaro does give the community an economic edge over some of its less well-placed neighbors where drugs are not easily trafficked. But rather than build true, lasting economic resilience, I theorize that the SES is actually made more vulnerable because of the inherent risks in the venture. Furthermore, rather than build upon or create true economic or ecological innovation at the local level, the narcotics traffickers are merely exploiting local knowledge of the border and the geographic isolation of the watershed. Instead, the narcoelites place the community and its inhabitants within a nested hierarchy that stretches from bases in Sinaloa, Southeast Asia, or Columbia to markets in the United States. The period of "creative destruction" that ensued with the neoliberal restructuring of the ejido created some of the opportunities for "investors" to place themselves within its structures, masking their activities, financial gains (by investing in cattle or land), and connections to both poles of the trade.

CHAPTER EIGHT: SUMMARY & CONCLUSIONS

"The man who is swimming against the stream knows the strength of it."
--President Woodrow Wilson, The New Freedom, 1913

As I have explored in the previous seven chapters, San Lázaro and the entire upper Santa Cruz River watershed have been transformed by a series of historical events broadly categorized as falling into biophysical, cultural, and political economic movements. These changes have not always been simple linear vectors in direction or predictable in impact and long-term outcome. Often the changes interacted to form new thresholds of change for subsequent political ecologic relationships. Following a thread of non-equilibrium ecological theory, we might find it useful to look for ways to categorize these changes in terms of both states and transitions. Each state is neither independent of its neighboring states, but is divided by a series of peaking transitions that yield high energetic or monetary costs for moving from state to a new one. Applying this theory to San Lázaro and the Santa Cruz watershed's particular political ecology yields us an understanding that change is temporary but that it catalyzes new transformations and that historical progress along an economic or biophysical trajectory is neither linear nor predictable.

The states and transitions model is further complicated by the interaction of biophysical elements within a particular system. In arid or semi-arid environments, the abiotic environment often dominates and masks interactions and effects of the biotic elements. Particularly, the abiotic environment may impact the availability and timing of moisture, which then masks the impact of herbivory on grasslands such as those surrounding San Lázaro. The herbivory in this case is generated by cattle and other livestock grazing. If the grazing is controlled by the presence or absence of acceptable forage, then we would assume that ranchers would then move their animals to better pastures and allow the original grasslands to recover. But evidence collected in nearby watersheds in Arizona supports the notion that rangelands don't respond immediately to the cessation of cattle grazing (Valone et al. 2002: 998). Rather, once a stable state has been created by shrub dominance and replacement of native perennial grasses, the conditions prevail for long periods (20-39 years in this case study). Time-lags abound in arid systems where limited moisture may mean slow or no recruitment for native grasses.

In this chapter, I will describe the states and transitions implied in the San Lázaro case study. In so doing, I will pay particular attention to the movement of biophysical, cultural, and economic elements through the community and build a case for feedbacks and potential thresholds that were created in the course of human settlement along the Santa Cruz River. But more importantly, I will focus on the impact and interactions of particular types of movements since it is the relationship between the biophysical and political economic that results in a more robust political ecology for this arid land community. Lastly, within this chapter, I will synthesize these relationships with the framework of the adaptive cycle.

Biophysical States in the Upper Santa Cruz and San Lázaro case study

The pace of ecological change in the Upper Santa Cruz Watershed is difficult to accurately document, due largely to the lack of good data from the Mexican side of the border. Only the fact that the Mexican-reach of the watershed shares much in common with its northern neighbor allows us to draw a relatively useful reference for baseline conditions. Comparing the two sides of the watershed is not without difficulties too, as the U.S.-portion has also been subjected to a range of vegetation-, soil-, and hydrology-altering forces. Principally, climate variability as I documented in chapters two (Figure 2.4, page 37) and six (Figure 6.4 and 6.5) generates the strongest signal. Data from two United States Geological Survey (USGS) gauging stations also illustrates a history of variability in stream flows punctuated by extreme events occurring in unpredictable intervals (Figure 2.3).

As can be seen in Table 8.1, the biophysical regimes of this case study within the upper watershed have three major components: oak savannahs, riparian woodlands, semi-desert grasslands and dynamic hydrologic conditions. Grazing, farming and other land management activities on the floodplains and uplands can be implicated in conversion (transitions) between of savannah and grassland communities into shrub-dominated plant communities. An author-initiated survey of rancher perceptions also indicates that infiltration has been severely reduced in recent years. Fifty-two ranchers said yes to the statement that water runs off the land more quickly (N=69).

As I mentioned early in this chapter, climatic variability has likely also masked or influenced the impact of herbivory on upland plant communities. Controlling for this variability can be achieved by excluding herbivory across similar plant communities and measuring grass and woody vegetation densities and frequencies in both grazed and ungrazed conditions over a long climate period. Group Five, with help from the Sonoran

Institute constructed exclosures for seed bank (see Figure 8.1) and wildlife habitat production that have generated some visual data on the presence or absence of perennial and annual grasses once livestock grazing has been removed, though no intensive plant surveys have been conducted within and outside of the structures.

Figure 8.1. Grass seed bank in Milpillas Division, San Lázaro, Sonora. Photo by the author.

Intensive use of the riparian areas has resulted in greater channel instability, lowered recruitment of dominant riparian woody vegetation (cottonwoods and willows), and increased less palatable mesquites in some cases. Floodplain farming augmented flows to these plant communities but simultaneously caused their conversion into fields that restricted the green line of galleried forest to the stream margins. Grazing in the riparian area has also contributed to areas of bank erosion, aggradation and broadening of the channel (downstream from San Lázaro) preceded by entrenchment within the community's reach. Upstream and downstream extraction of surface and subflows has lowered the stream's baseflow since the *acequia* was originally constructed.

Biophysical Regimes:	1. Oak Savannah of mixed *Quercus* spp. and continuous populations of semi-desert bunch grasses in uplands. Colonies of mesquites (*Prosopis* spp.) restricted by soil, fire and moisture availability. Patchy fire is an annual or semi-annual occurrence. 2. Uplands are bisected by *Prosopis* spp. woodlands as well as Fremont Cottonwood-Goodding Willow galleried forest complexes in the riparian bottomlands. Dense development of multi-galleried herb, shrub and tree layers. Stream flow is intermittent to continuous (perennial). Periodic flooding encourages movement of woody debris and high recruitment of cottonwood and willow populations. Channel geometry is stable with little entrenchment or widening. 3. Sparse semi-desert grasslands of annual and less livestock-palatable herbs and an overstory of unpalatable shrub cover. Soil compaction by livestock, significant soil erosion, and lowered infiltration of precipitation. Fire is restricted leading to increased mesquite encroachment. 4. Riparian vegetation is restricted to perennial reaches of streams, with recruitment highly reduced and or eliminated. Large woody specimens dominate with little structural variability in subgalleries. Stream flow is ephemeral to intermittent. Streams demonstrate either aggradation or degradation with little channel geometric stability.
State 1 (approximately 1680-1959):	Historically, sparse grazing on uplands and intensive farming of bottomland floodplains.
State 2 (1959-1990):	Intensive farming of bottomland floodplain, removal of woody riparian vegetation by grazing, fuel wood cutting, and extensive livestock grazing of upland Oak Savannahs and grasslands. Increased soil erosion and stream instability.
State 3 (1990-2003):	Sporadic farming of bottomland floodplain, incursion of woody riparian vegetation into agricultural fields. Conversion of extensive to intensive livestock grazing in specific pastures in Oak Savannahs and grasslands. Abandonment of other pasture areas as they convert to shrub-dominated regimes. Increased soil erosion and lowered infiltration rates.

Table 8.1. Summary of four major environmental regimes and three documented ecological states in the Upper Santa Cruz Watershed from the San Lázaro case study.

Political Economic States and Transitions in Sonora and the Upper Santa Cruz

As in San Lázaro, cattle culture is everywhere in Sonora. The modern state stands behind five others in the prominence of its cattle production--Chihuahua, Durango, Michoacan, and Tamulipas (INEGI 2000). Sonora's biggest agricultural commodity is wheat, followed by seafood, pork, and vegetables. Yet, the state revels in its cowboy chic, like Texas or Wyoming in the United States. In Hermosillo, the largest urban center, cowboy boots are fashionable to parties, with business attire, and for casual wear. Ranching influences are found in the music, the arts, and the state's native commercial advertising. Yet, in spite of all of the hype, the state is still a major center for cattle breeding, production, confined feeding operations, and new technologies. Ranching does dominate the rural areas of the state, particularly the more humid portions along the front of the Sierra *Madre* Occidental.

The shear bravado of the Sonoran's pride in ranching, however belies the real status of cattle production--one of steady decline and replacement with new livelihoods in the countryside. In the case of narcotics smuggling, these are more lucrative, while other pathways such as those associated with wildlife reserves, migration, off-farm labor, or mineral leasing are less certain in payoff. While Sonoran cattle ranching in the last century has experienced a technological and financial explosion in response to massive shifts in markets, economic policy, and government stimulation, in the last few decades it has been surpassed with other economic engines. Furthermore, the decline of the cattle industry in Sonora has exacerbated historic differences between large and small producers. This last condition is one that impacts the border region in particular, as the impacts of beef exports and imports are most acutely experienced in operations that depend upon or are directly impacted by cross-border trade in hides, beef, calves, and adult cattle.

New Economics of Livelihood

The localized political economy of San Lázaro now reflects the new economics of a globalized and at least partially integrated Mexico. Households purchase their foodstuffs from markets, grow less of their food than their predecessors, and thus have fewer ties to the local landscape. As I discussed in Chapter Six, the 12 out of 104 households who actually raised food on the floodplain are now an anomaly rather than the norm. This is a reflection of Mexico's shift from protected domestically-focused agriculture that supported economically nationalistic goals or import substitution modes to an articulation on global markets for beef, pork, and other commodities for wealthy trading partners (the United States primarily but also Canada, Europe and even Asian countries). While food insecurity has grown in rural and urban Mexico, its global position in food or agricultural commodity production has increased. For example, Mexico is now a world leader in the production of sorghum for cattle feed, yet at least 35 percent of its population do not eat meat regularly if at all because of food insecurity (Gates 1988: 283).

In San Lázaro, that shift is no less obvious to the observer. Where during the ejido's peak years from 1960s-1980, cow-calf operations were still paramount in importance, the ejido was more diversified as an enterprise. For example, *ejidatarios* ran dairy cattle near Agua

Zarca, raised apples on 48 hectares of floodplain, and raised a significant area of wintertime vegetables for the domestic and local consumption. By the 1990s, the ejido had abandoned most of these elements in favor of forage for cattle, and had eliminated the dairy altogether. The privatization that took place in the 1990s meant that individual rancher-farmers were responsible for their own floodplain parcels. With the infrastructure problems plaguing the irrigation system, most sold out, leaving just a few entrepreneurs to raise vegetables or forage. As of 2003, forage was the dominant product (constituting at least 69 percent of the floodplain's use).

Tenure vs. Management

As can be seen in Table 8.2, a series of tenure arrangements reflected the management regime in San Lázaro over the last 100 years. These arrangements also reflect—to a limited extent—the dominant ideologies of the times. During the first half of the 20th century, private property was the dominant tenure system, even as the Mexican government outwardly demonstrated its patronizing largess to marginalized *campesinos* by assigning lands to them along with subsidies designed to build long-term political hierarchy. But under the surface, big business and foreign investment still dominated some sectors of the Mexican economy. When lands were appropriated by the Mexican government for ejidos, they were not the most favorable lands and were not created to antagonize large-scale capitalist industries. But land management under the private regime of William C. Greene was perceived as relatively benign and though there is little environmental data to support this or a case of ecological change. The available data support the conclusion that because Greene and his Cananea Land and Cattle Company controlled such vast areas of the northern Sonoran landscape, he had the luxury of moving livestock around frequently, could rest pastures as long as was necessary, and had sufficient control over market share to be able to command acceptable prices for livestock sales, even under less than ideal circumstances. These last two facts allowed the North American capitalist to practice an early form of what is now called "adaptive-management." Walters (1986: 8) characterized adaptive management as working from "the central tenet that management involves a continual learning process that cannot conveniently be separated into functions like 'research' and 'ongoing regulatory activities', and probably never converges to a state of blissful equilibrium involving full knowledge and optimum productivity."

Conversion of Greene's empire into a set of smaller, more intensively managed ejidos operated by a collective of rancher-farmers and the Mexican state altered this management regime by removing some flexibility and increasing density of people and use across the landscape. This does not mean, however, that the ejido was less able to adaptively work the landscape with some degree of resilience. During the hey-day of the ejido period, The organization of tenure in Ejido Miguel Hidalgo and other arid land communities was ideal for the management of natural resources such as common pool rangelands and irrigation systems. Although floodplain farming was perhaps best adapted to household-level intensity (cf. Netting 1993; Sheridan 1988), the collectivized organization of these two other vital aspects of rural livelihoods in San Lázaro managed to spread economic and environmental risk among a larger population of households. This is especially true in light of the environmental variability of both rangeland and water resources. Obviously, though the ejido did not have much time to adapt this form of management to best fit all variability. On more than one occasion, nature—who always bats last as the bumper sticker goes—sent one out of the ball-park in the form of a major flood or drought period. Yet overall and perhaps by serendipity rather than strategic design of the Mexican government, the collective system allowed for more adaptation to the vagaries of watershed conditions for rancher-farmers than the period I will describe next. The state's usurpation in lower-level resource decisions (Rappaport 1995: 273f) forced ejido members to make decisions that did not fit with the local circumstances.

As the end of the 20th century neared, however, the state level interference took on a new more negligent character that had generated a whole host of problems for the community, especially when coupled with environmental consequences that are felt most acutely in San Lázaro. The application of a neoliberal model of development favored the creation of strong property rights, easy movement of investments, free trade of goods across the nearby border, and little regulation or enforcement of environmental protections. In San Lázaro this meant the privatization of individual parcels of floodplain agricultural land, and small group management of range parcels rather than collective organization of range resources. Water too was at least partially privatized through a de facto market that has had ironically positive results for short-term reactivation and refurbishment of wells on the floodplain but a host of potential long-term downsides that have yet to manifest in the San

Lázaro portion of the watershed. The most important impact of these changes has been in the form of land concentration and a rise in outsiders utilizing the both the floodplain agricultural zone and the ranges. Livelihoods, as alluded to earlier in this chapter, are now concentrated in largely non-agrarian strategies. At the same time, local decision-making and organization have both diminished significantly, meaning resource control is now outside of the preview of a majority of community members who no longer participate in the production of local agricultural commodities and who no longer have a stake in environmental outcomes of such activities. This has reduced social capital significantly and increased the elite nature of resource management, rather than decentralizing it as was the intent under the neoliberal reforms.

Period:	**Tenure Regime:**	**Management Regime:**
1901-1958	Private Property	Capitalistic management of farm and rangelands by local foremen under direction of single owner-operator (Greene and heirs)
1959-1988	Communal Property (Usufruct of Federal Trust Property)	Collectively managed rangelands and farm parcels with significant state oversight and intervention
1988-2006	Communal Pastures	Small-group and/or individually managed rangelands with little outside intervention
	Titled Farm Parcels	Individually managed farm parcels

Table 8.2. Summary of tenure and management regimes in San Lázaro, Sonora during the past century.

The New Distribution of Risk

The rearrangement of tenure can be likened to a transitional force in the states and transitions model of the Upper Santa Cruz Watershed and the social-ecological system (SES) that is San Lázaro and its contiguous ejido. The nature and distribution of risk has changed in San Lázaro as a result of the new state that is a product of the neoliberal rearrangement of tenure. Risk has been centered on the individual householder or household rather than spread across a community of users. That risk can take the form of environmental risk from climate variability, floods or pests. It can also come in the form of economic risk which had previously delivered restrictions of credit, capital or labor as well as single or combined deficits of environmental "inputs" such as irrigation water or good forage. During W. C. Greene's period of ownership, the capitalist could absorb risk through his vast holdings and highly liquid assets (even after the mine at Cananea was wrested from his control in 1911). He could move cattle and other livestock (such as his thoroughbred horse herds) across several climatic zones and between three watersheds (San Pedro, Santa Cruz, and Río Cocospera).

Once the ejido was formed in 1959 and collectivized the Mexican Federal Government—through its financial and rural development agencies—sought to spread risk across the 142 households of San Lázaro while also erecting a firewall to risk for themselves through layers of local to national bureaucracies. Though ultimately a failure, the Unión de Sociedades Ejidales de Crédito Colectivo Ganadero de Cananea Sonora was a government inspired attempt to spread risk throughout the seven ejidos of the Greene ranches. The USECCGCS was at least partially and superficially designed to move produce from one ejido to another in a way that might have offset temporary shortfalls in production. The

USECCGCS ultimately failed, however and was widely perceived as a vehicle for government control of ejido affairs. The fact though that cattle herds and farmland were managed collectively meant that no single household would be responsible for absorbing environmental risk in a flood or a drought.

The meso-organization of the ejido within a nested hierarchy had several impacts on the adaptive cycle that San Lázaro was experiencing from at least the first decade of its new life (1960-1970). First, it significantly reduced the community's ability to leverage local knowledge into appropriate management. In this sense, the creation of hierarchy and bureaucracy also reduced the community's ability to develop its own cultural capital (local knowledge) and innovate in response to environmental variability. In linking the community to other ejidos, the government created more "connectedness" that increased the SES's sensitivity to disturbances (Walker 2006: 14).

The strictly-enforced Mexican hierarchy, however, is not just indicative of trends in local knowledge and agency that impact the "adaptability" of the community to environmental change. It also suggests that San Lázaro and its rancher-farmers sit within nested fields of power that emanates from ideologies and other technologies of power (Ghani 1995: 32; Wolf 1999: 2). These fields of force to quote Eric Wolf (1977: 33), are found in such technologies as political patronage, agricultural development schemes, structural adjustment policies, credit institutions and trade agreements. I have demonstrated herein that each of these have played an important role in determining the community's ability to effectively manage ecological or economic crisis. I argue here that the concept of the adaptive cycle is useful for its organizational framework but not entirely for its explanatory abilities. The issue of power is better addressed through some of the tools that political economists and political ecologists have developed. These may better explain the unequal development that has impacted San Lázaro from its beginnings to present.

The tenure of the ejido itself—as a federal trust held for the member—meant that the government was to make up for these unforeseen events with technology transfer, credit, and grants of aid in times of disaster. Yet, on several occasions, particularly when the infiltration gallery was destroyed in the flood, government largess was too little or non-existent. The federal government's reticence to invest in the ejido during bad times was also, however, a product of the economic crisis it faced during the 1980s and later a requirement of the Structural Adjustment Policies (SAPs) instituted as a response to the crisis. Lastly, there was an important political downside associated with the promise that the federal government would absorb economic or environmental risk: the patron-clientalism of the PRI would be maintained for 71 years by voters in ejidos like Miguel Hidalgo.

On the other side of the coin, the ejido and its individual members lost significant autonomy to manage their own affairs in the face of risks that were obvious to them but not the government bureaucrats. Because of the top-down hierarchy, the leadership of Ejido Miguel Hidalgo could not manage its own finances without federal oversight through Banco Ejidal. This monopoly on credit led, perhaps, to the corruption that forced the local branch of Banco Ejidal to burn its records on the main street in Cananea. It also lead to the perception that the ejido was being pushed to adopt riskier practices in the form of higher stocking rates that benefited this creditor and not the ejido's long-term health (see Figure 6.6). The strict control of credit had other impacts as well. Individual rancher-farmers could not obtain credit themselves to try new technologies and were dependent upon agencies to dole out the resources for them. Innovation and diversity of resources in the SES was therefore severely restricted. From the perspective of the *ejidatarios*, their more capitalized counterparts in the private sector could take full advantage of whatever technological innovations presented them given the appropriate environmental conditions. These better-capitalized ranchers could also respond more rapidly to environmental risks such as repair a flood-damaged infiltration gallery or purchase additional forage during a dry year. Ranchers with greater access to higher-level resources (financial capital or credit) were more resilient in the face of ecological disturbance because of their cross-scale (financial) linkages. Kinship, social capital, and economies of scale all play into the ability for the private sector to respond quickly to changing variables.

At the same time, flows of credit and government subsidies have diminished to a trickle in the era after the initial structural adjustments, or at least were diverted towards other participants in Sonora and Mexico (c.f. Heyman and Greenberg N.D.: 2f). While these resources themselves are critical to economic success of the ejido members and their community, it is more useful to look at how the neoliberal transformation reassigned risk across sectors of the ranching and agricultural community. The neoliberal transformation of the ejido into a privatized regime resulted in a significant shift in risk away from the community and towards the individual household or operator. Individual operators are now responsible for their own forage and negotiating their own contracts with buyers at the end of the season. A dry year could put such a rancher out of business if he cannot feed his calves and cows enough to tide them over to sale in the fall. We have seen how the agricultural fields on the floodplain are tied to the dry rain-fed range. When the government was unwilling and/or unable to pay for the repairs to the *acequia* system after the floods of the 1970s and 1980s, the result was a de-linking of the two systems. Before the loss of dependable irrigation water a rancher-farmer could depend upon his or her fields to produce dry-year or dry-season forage (or at least cash to purchase the forage). Now the rancher is just a rancher—not also a farmer.

The drought years beginning in the mid-1990s put this new configuration under great strain and when coupled with the dip in calf prices at the same time, forced many cow-calf producers out of the business altogether, to be replaced by others with the financial wherewithal to purchase their own supplemental forage. To bolster this argument, in Appendix D, I have provided a series of satellite images that measure vegetation or "greenness" of the watershed over the course of a weak "La Niña" phased year (2001)—one that was particularly poor for ranchers trying to fatten cattle off of strictly rain fed pastures. These normalized difference vegetation index (NDVI) data are provided by the Arizona RangeView program (http://rangeview.arizona.edu) through its web-delivered tools. NDVI is a normalized ratio of the near infrared and red bands. These data are provided by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument. The reader should note that the uplands green up (turning shades of brown which indicate more cover) considerably during wet or average monsoon years, at the same time that riverine fields go fallow (and appear darker blue which indicates lack of cover).

Because of the unfortunate intersection of uneven government involvement, new political economy, and vulnerability to climate variation, I argue that the majority of the 104 remaining households no longer practice agriculture in the ejido, nor participate in its management because the risk of loss during dry years is too great. Despite high prices in the U.S. market, the cost of raising a cow-calf unit for market is too great to be borne by a single operator with only a few hectares of rain fed rangeland, particularly because of the lack of inexpensive forage from the floodplain in the last decade and a half. In an exceptionally dry monsoon season, the extra forage production that was possible there during the ejido's collective period was a considerable cost-savings as compared to purchase of expensive bales of hay that a solo operator might need to purchase during spring calving and fall fattening prior to sale in the market. Cash crop production too on the floodplain provided a ready substitute of either food or supplemental cash that could be budgeted towards forage for cattle in dry times. Without cattle to support, only 12 *ejidatarios* continue to farm the floodplain and have either leased or sold their shares to outsiders who have more resources to deal with risk in dry years, such as the illegal pumps.

While no survey data will explicate this, the signs and anecdotal evidence point to a case that many of those who have replaced the original *ejidatarios* in San Lázaro in the cattle ranching business are doing so to dispose of extra cash resources garnered through the drug trade as has been recorded elsewhere in Mexico (c.f. MacDonald 2005). Ranching is still very much perceived as a way of life and even an honorable, *muy macho* practice for businessmen in Sonora. The businessmen currently involved in ranching in this case have simply raised funds through the covert rather than over economy. Yet their access to ready cash allows them to purchase the inputs such as unsubsidized vaccinations, supplemental forage, and equipment necessary to maintain a foothold in the cattle ranching business. In the meantime, as I explained in Chapter Six, only 22 percent of ejidatarios surveyed by the author stated they made their primary living from cattle ranching. With the government's withdrawal of subsidies and credit, a new, covert bank has entered the community though the costs—or more accurately risks—involved in opening an account can be extremely steep.

In the meantime, the ability for those who still hold title and ready access to the floodplain must wait for this option to become a more stable one. As of 2006, the process of sharing the benefits of new pumps and concrete-lined *acequia madre* canal were not clear to the author. But the sale of the water rights to the mining company Peñoles has undoubtedly left the ejido with fewer acre-feet of subflows to extract, meaning in dry years or as competition upstream increases, it will be faced with some type of handicap the magnitude of which is also not clear.

At the Confluence: Biophysical and Political Ecological Feedbacks

I have advanced an argument that new vegetation regimes, significantly accelerated soil erosion, changes in fluvial geomorphology of bottomlands and regional-scale climate variability have led to a severe disadvantage for the newly privatized rancher-farmers of San Lázaro. As part of a larger feedback cycle, these environmental changes have driven the choices that community members have made for livelihood strategies, including the integration into the covert economics of narcotics smuggling. Figure 8.1 expresses these relationships in a simplified graphical way. Each cycle encompasses biophysical (ecosystemic) and political ecologic processes (privatization, livestock management, off-farm livelihood strategies). Notice that in this model it is impossible to separate the biophysical processes from the economic cycles.

Yet this model does not capture some of the dynamism of the interactions, nor does it accurately build a sense of chronology. In fact, the cyclical nature of each feedback loop means that it can return to its original state eventually. This contradicts everything discussed in Chapter Three—that arid systems have processes in play that cannot return to their original state because there is no original state to return to. This can be true of riparian systems too—in place of aridity is dynamic change generated by dynamic fluvial geomorphology. Streams are always actively modifying their channels and in doing so, transporting sediment, water and organic debris through the system. So cyclical feedbacks might work, but can only accomplish so much when it comes to this arid land case study—they only depict obvious relationships.

On a theoretical level, we are trapped by the ability to effectively perceive, and analyze the totality of processes in the upper Santa Cruz and even in San Lázaro. The primary issues I have defined here: hydrological conditions, geomorphologic change, climate variability, range condition, and long-term economic livelihood strategies for people dependent upon these are all processed through a vexing epistemological dilemma. This relates ultimately to the way they are studied and ultimately how their management is applied. The nexus instead becomes a fuzzy, difficult point for me, as the researcher, to tease out of the data. For this reason, sciences (both biophysical and to a lesser degree, social) have sought to work in a reductionist fashion, with the ultimate goal that the conclusions can be re-woven together with their original counterparts. But as has been discussed at length in the post-modern era, reducing phenomena to their constituent parts eliminates any ability to say something meaningful about the whole system. Social scientists have attempted to return to this issue, but are not followed by their colleagues in biological, or physical sciences (excepting perhaps some theoretical physicists). In fact, for sake of this study, new ecological insights are among the most important contributions to understanding the political ecology of arid land watershed and community. Yet ecologists have become even more reductionist in their approaches, leading many to conclude that the study of ecosystems is perhaps dead, if not ailing. In this sense, we are trapped by division between the social and the biophysical sides as noted by John Bellamy Foster (2002: on-line):

> *The ultimate strength of Marxist analysis has never resided chiefly in its economic crisis theory, nor even in its analysis of class struggle as such, but lies much deeper in its materialist conception of history, both human and natural-understood, as this only truly can be, as a dialectical and endlessly contingent process. This means overcoming in a nonreductive way the split between natural-physical science and social science that has been one of the main alienated intellectual products of bourgeois*

society.

The nonreductive, dialectical means to this end is to begin to look at the system as a sum of contingent processes, not parts. Processes here may be defined as management, disturbance, ecological change, resilience and movement from state to state across a series of pathways and through ecological thresholds. This is where we return to the states and transitions modeling technique briefly discussed in Chapter Three.

Range and Riparian States and Transitions in San Lázaro

Applied ecological disciplines from which political ecology might draw both inspiration and methodological insights, are necessarily organized around response models such as climax, or states and transitions. The litmus test for an ecological model is its ability to predict the consequences of disturbance or human activity (defined as management) (Stringham et al. 2003: 106). As I discussed at length in Chapter Three, traditional theories of plant succession based on Clements climax community concept have been found to be inadequate for understanding the complex pathways of change in semi-arid and arid ecosystems. In modeling change in arid systems, many researchers in range management (e.g., Archer 1989; Rietkerk and van de Koppel 1997; Westoby et al. 1989) and a growing number in riparian scholarship (e.g., Baker and Walford 1995; Stringham et al. 2001) have adopted the states and transitions approach to modeling process.

States and transitions modeling rests on three major concepts: an ecological state; transitional pathway, and ecological threshold. States are defined as recognizable, resistant and resilient (Gunderson and Holling 2002), complex of two components including a soil base and a vegetation structure. These two components are connected through ecological processes including nutrients, production, and hydrologic relationships. Transitions are defined as discrete trajectories of change that can be precipitated by natural or anthropogenic events which degrade one or more of the states primary ecological processes. They may be reversible or not, depending upon if a particular ecological threshold has been crossed. The resilience and resistance of a state at least partly determines a transition's reversibility. Once a threshold has been crossed, enormous, generally unpractical levels of input are needed to restore the state to its previous condition. Thresholds may be defined as boundaries in space and time between any or all states along irreversible transitions (Stringham et al. 2003: 109f).

Figures 8.3 and 8.4 are states and transitions models that I have developed to explain processes occurring in the uplands and bottomland components of the landscape controlled by Ejido Miguel Hidalgo and its surrounding neighbors in the Upper Santa Cruz Watershed. Grasslands, oak savannahs and riparian woodlands can all be illustrated as the mobile, fluid results of ecological processes. In each case, the transitional inputs may be climatic or anthropogenic. In some cases, particularly at the threshold producing event of long-term drought, continued management towards maximizing individual holdings results in energetically expensive transitions into new states represented by increased shrub coverage and a loss of perennial grasses for the foreseeable future. The states and transition model of riparian bottomlands is more difficult to assign clear transitions or thresholds because of the dynamic processes at play including changes in stream baseflow, sediment transport and recruitment of new vegetation. Because of their dynamic abiotic conditions, riparian ecosystems tend to be characterized by high resiliency (Baker 2004: 320). Anthropogenic impacts are primarily concentrated in the removing vegetation and reducing stream bank stability through livestock grazing.

States and transitions modeling force the arid system political ecologist to do three important things: 1) to acknowledge that shifts in state from one to another are non-linear and do not correspond to either equilibrium and non-equilibrium conditions; 2) to acknowledge that states are independent and not necessarily reversible without vast inputs of energy (usually more than a system can produce); and 3) to acknowledge that biotic and abiotic factors are both at play in a particular system, generating multiple pathways (transitions) and one or more thresholds between states. Condition three tells us that because of the irreversibility of ecological transitions, management inputs to correct a particular condition may be misguided because they do not muster sufficient energetic inputs to move back over the threshold. Of course, one caveat needs to be said here with regards to the new ecology of state and transition models or the conception of multiple stable states. We must heed the advice of geographer Zimmerer that this conception means we can "justify environmental degradation by humans generally or social interests in particular" (1993: 115). Rather, this model gives political ecologists a different set of parameters in which to comment on human-environment interactions: humans have generated stable states while also undermining their ability to restore their environments to previous states.

Most importantly, applying Gunderson and Holling's (2002) central concept, it is the resiliency and resistance of the ecological states that allows them to be moved down particular transitional pathways. Resiliency in this case is the ability of the system to self-repair or adjust while resistance is defined as the ability of the system to remain the same while external conditions change. This idea too may be applied to communities such as San Lázaro just as much as the study of ecological states at the site level can be scaled up to predict outcomes at the landscape-scale.

Each political and ecological event has perturbed the community's state across its range of resilience and resistance. Floods, droughts, government action and inaction have all increased the vulnerability of some segment of San Lázaro's society and pushed it towards a set of economic and ecological changes that now seem irreversible in some cases without great amounts of input. The resiliency of the community—its ability to recover from crisis such as the flood damage to the infiltration gallery was compromised by the Mexican federal government's unwillingness to respond with assistance to repair the irrigation intakes and the community's lack of other options. Diminished and novel resources reduce the ability of the system to recover from disturbance. This has caused reorganization for the entire SES, eliminating some social classes while encouraging and emboldening others (r-strategists such as investors from outside of San Lázaro). The lack of steady flows into the acequia meant that farmers were unable to raise supplemental feed for cattle that would tide them over during drought. The community too, has resisted change in some cases, refusing further bank interference in their affairs in the early 1990s.

The omega-phase of creative destruction that resulted from the confluence of ecological changes with new economic and policy signals in the late 1980s and 1990s has created new opportunities for some actors such as the Sonoran Institute, group five, extra-local businessmen, and even the narcotics traffickers. The Sonoran Institute has encouraged innovation for those best organized to undertake it, namely group five. The narcotics traffickers could take advantage of a young, regionally isolated population hungry for new economic opportunities that could not be provided by moribund agricultural livelihoods. The additional funds produced by elites involved in narcotics trafficking has allowed the community hold together and resist the massive out-migration that other communities in Mexico have experienced in the past 20 years despite the lack of local profits from cattle production. The dependency, however, of the community on these new monetary flows might not bode will for its continued resiliency if they were to dry up.

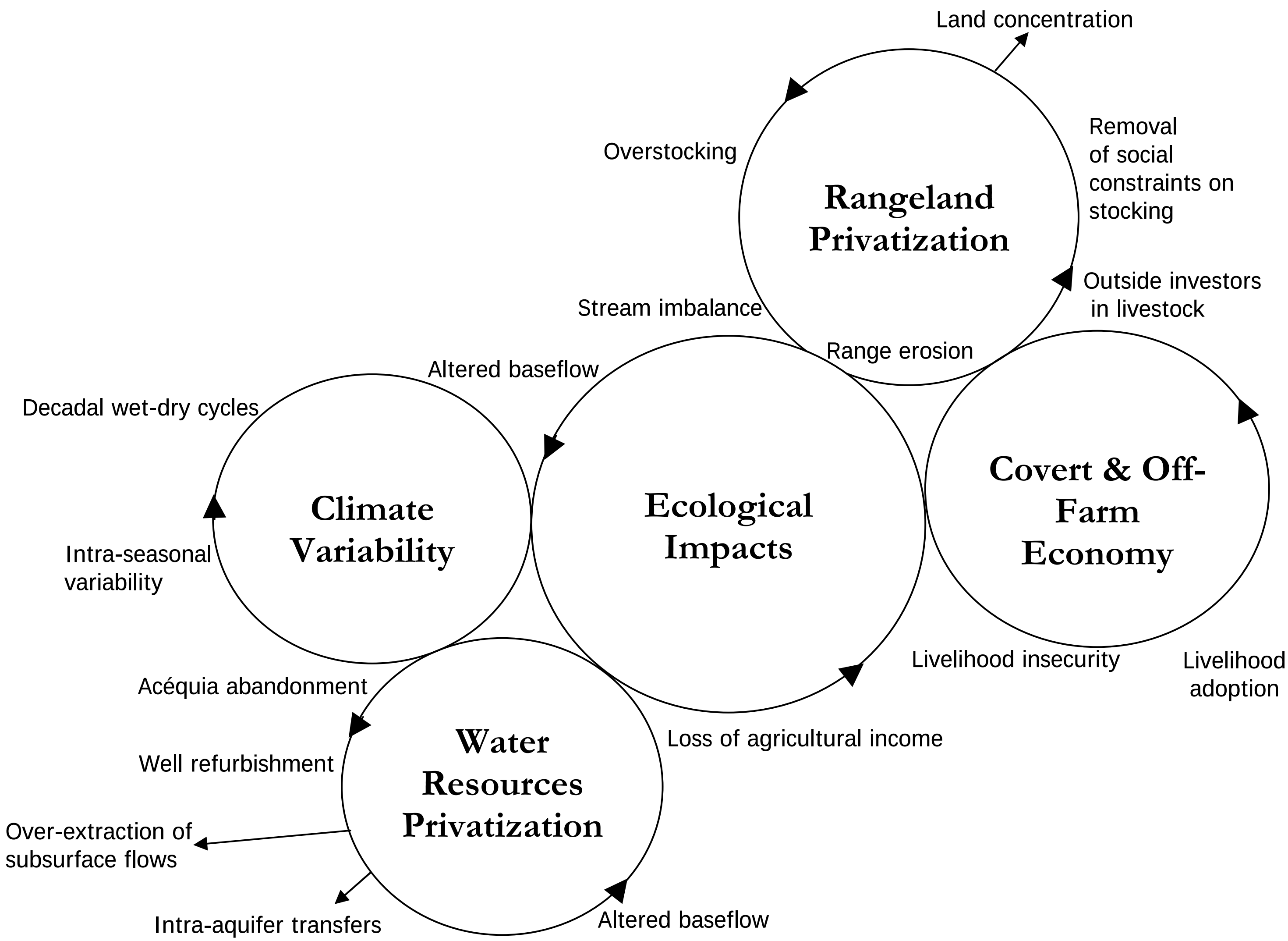


Figure 8.2. Simplified model of feedback cycles in the San Lázaro case-study.

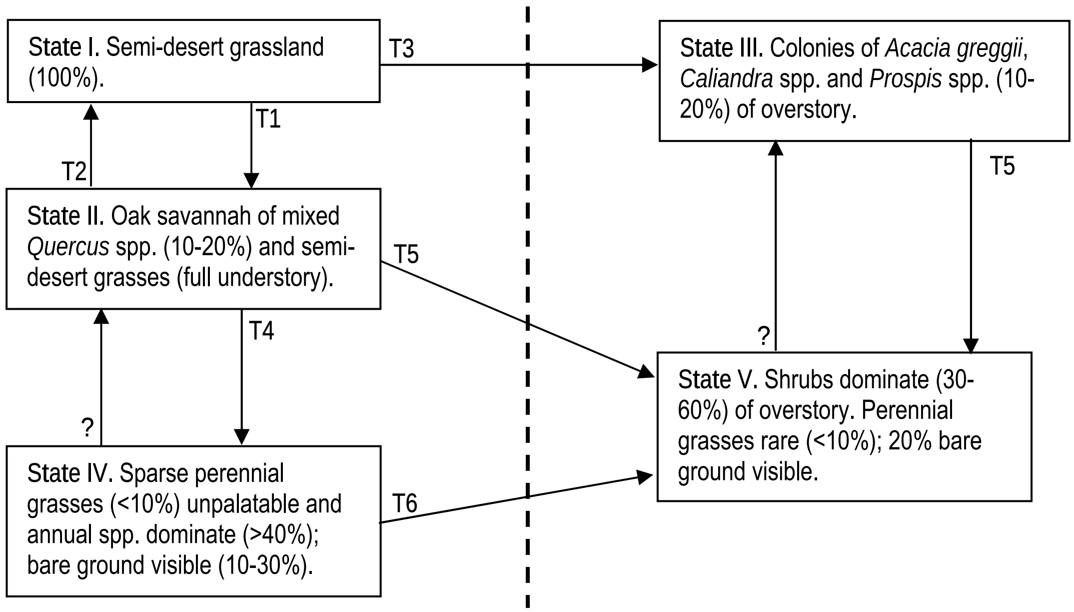


Figure 8.3. Oak savannah and semidesert grassland states and transitions model for the San Lázaro area. The dashed line represents a threshold event of drought.

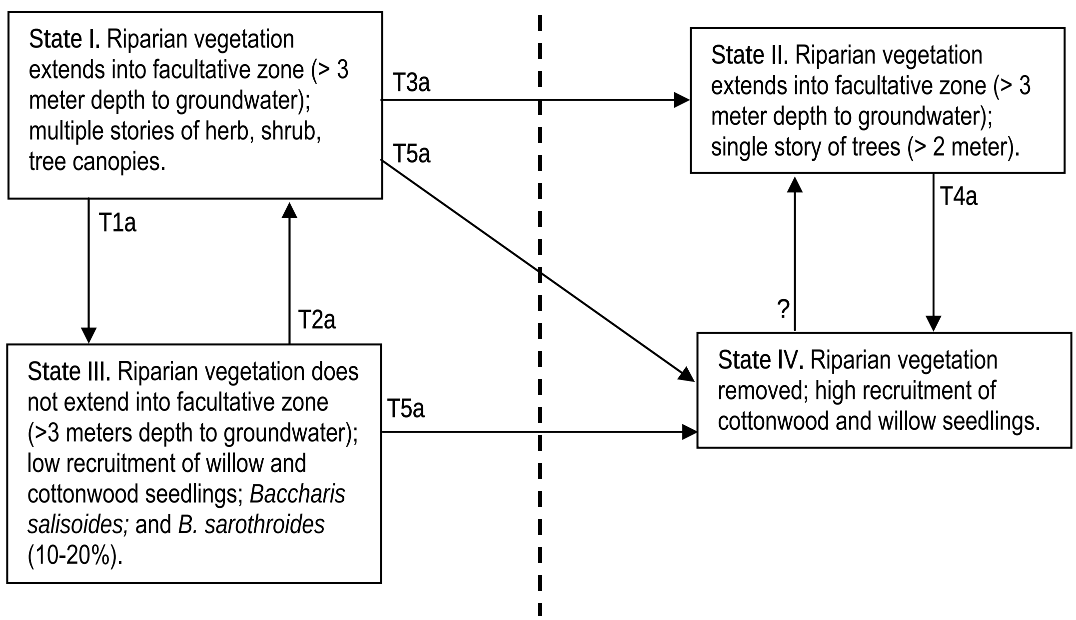


Figure 8.4. Cottonwood-willow riparian area states and transitions model for the San Lázaro reach of the Santa Cruz River. The dashed line represents an extreme (100 year) flood event.

Catalogue of States: Uplands

State I: Semidesert grassland is relatively contiguous across large patches of landscape (hectare plus). Soil moisture retention is high relative to states IV and V while rainfall damage is low if present at all.

State II: This state is characterized by oak savannah of mixed *Quercus* spp. constituting at least 10-20 percent cover with an understory of semi-desert grasses. Patches of oaks may be found throughout less contiguous grasslands. These oaks are also accompanied by other interior chaparral forbs. Rainfall runoff in all but extreme events is low while soil moisture infiltration is relatively high compared to states III, IV, and V.

State III: The semidesert grassland is colonized by *Acacia greggii*, *Caliandra* spp. and *Prospis* spp. which then constitute at least 10-20 percent of overstory. In this state, grasses are scarcer and rainfall runoff is more conspicuous. Damage to soil surface may be visible.

State IV: Perennial grasses are subdominant to rare, constituting less than 10 percent of vegetative cover. Unpalatable, aggressive herbaceous and shrubby plants dominate at greater than 40 percent of soil coverage. Bare ground is visible and may range from 10-30 percent of landscape coverage. Rainfall damage to the soil surface and runoff may be high; hence soil moisture retention is low.

State V: Shrubs tend to dominate this state's overstory with 30 to 60 percent coverage. Perennial grasses tend to be very rare at less than 10 percent cover while significant (20 percent) exposed soil is visible. Rainfall damage and runoff are expected to be high with low rates of soil moisture retention, depending upon the season.

Catalogue of Transitions: Uplands

T1 (I-II): Grassland converts to oak savannah as a result of increased moisture, cooler temps, infrequent fire allows seedling invasion. Timescale is long (greater than 100 years).

T2 (II-I): Conversion from oak savannah back to grassland by decreased moisture, warmer temperatures, and frequent fire to remove seedling recruitment. Timescale is long (greater than 100 years).

T3 (I-III): Removal of grasses by sustained herbivory coupled with drought. Timescale is very short (5-10 years).

T4 (II-IV): Increased and sustained herbivory in oak savannahs. Timescale is very short (5-10 years).

T5 (II-V, III-V): Sustained herbivory along with infrequent fires. Timescale is moderate (50-75 years).

T6 (IV-V): Crown fire removes oaks, herbivory, disease or fuel wood cutting removes remaining trees. Long-period cutting of trees may also replicate this pathway, though less likely because mesquite is a more desirable fuel wood. Subsequent to stand removal, less palatable or useful species invade that can resist removal by herbivores or humans. New climax state achieved. Timescale is short (1-10 years).

Threshold (dashed line) equals severe drought, lasting longer than two years, and allowing for interruption of intraseasonal precipitation.

Catalogue of States: Riparian Area

State I. Riparian vegetation extends into the facultative zone above bankfull and below the first historical flood terrace. Groundwater depth in this zone is greater than 3 meters. In the obligate and facultative zones, multiple stories of herb, shrub, and tree canopies are present. Structural diversity is present.

State II. Riparian vegetation extends into the facultative zone (where depth to groundwater is equal to or exceeds 3 meters). Structural diversity is far lower than in State I., and is characterized by a single story of trees that may be senescent. Herb and shrub layers are nearly non-existent. Recruitment of young cottonwoods and willows is low.

State III. Riparian vegetation does not extend into the facultative zone. Recruitment of new cottonwood and willow seedlings is exceptionally low. Seep willow (*Baccharis salisoides*) and desert broom (*B. sarothroides*) are more common, constituting ten to twenty percent of forb and tree coverage.

State IV. Riparian vegetation is almost entirely removed (remaining covering 10-20 percent) of surface area). Abundant cottonwood and willow seedling recruitment.

Catalogue of Transitions: Riparian Area

T1a (I-III): Stream entrenchment creates new, lower active channel and drop in groundwater levels. New facultative riparian zone created but in new terrace only.

T2a (III-I): Sustained herbivory of seedlings and invasion of opportunistic unpalatable species.

T3a (I-II): Sustained herbivory of seedlings and herbaceous species. Little soil particle build up.

T4a (II-IV): Sustained herbivory does not allow for seedling recruitment. Baseflows are significantly lower and subflows less available to riparian species.

T5a (I-IV; III-IV): Catastrophic flooding scours channel, removes most woody debris and biomass.

The Adaptive Cycle in San Lázaro: a Synthesis

As I have asserted throughout this study and especially apparent within the states and transitions model presented above, ecological change very often parallels and/or feeds social change. The concept of the SES provides a holistic means of accounting for this dualistic nature of human-environmental interactions by acknowledging that social, political and economic factors influence and are in turn influenced by the processes of ecological change. These transformations can be contextualized within nested adaptive cycles of change that respond to pre-existing conditions and which provide new opportunities for system actors. The adaptive cycle acknowledges that processes of social and ecological change may be permanent, irreversible and result in new configurations not previously imaginable. In other words, these new configurations constitute multiple stable states. The ability for an SES to respond to these processes of change depends upon its resilience which defines the range of reversible change within a stable state. Resilience is determined by a system's vulnerability, as well as its stock of pre-existing or available capital. Centuries of use of the watershed may have reduced that capital. For example, entrenchment of the stream from *el Cajon* to the floodplain now limits the extraction of water for agriculture, but it is possible with experimentation to bring the stream into a poised or graded state with respect to its floodplain. All is not lost, just difficult to return to original, more desirable states.

Within this dissertation, I have asserted that resilience is an important factor to consider in studying arid land political ecology. Resilience can be influenced by both institutional and environmental factors. Institutional factors alone cannot explain the pace of change in a particular political ecology. While institutions constitute the dominant signals with regards to economic decision making, environmental signals may be ultimately more significant, or have the ability to draw the SES into a new state. In terms of the adaptive cycle, that state may be characteristic of a new phase in the adaptive cycle.

This case study demonstrates the influence of strong political and economic signals that influence local economics. Nature bats last and may exert powerful forces over institutional choices. These powerful forces were largely found in flooding and drought, even temporary ones. At each point, they resulted in a loss of resilience that given an external "push" lead to the propagation of a new phase of "creative destruction" (Ω-phase) or likewise, innovation (α-phase). Using this case study, I demonstrated how a dramatic shift in climatic as well as hydrologic regimes lead ultimately to a general degradation of agropastoral ecological resources in San Lázaro and their replacement with new, stable but less desirable states. Both land title and land-use have subsequently shifted, although the former was not as a direct consequence of ecological limitations. The set of ecological changes has become a sort of death of a thousand cuts that has reduced the community's ability to tap local natural capital and thereby generate economic capital.

On the other side of this story, however, is a more upbeat message that says that local agency, adaptation, and "memory" may result in positive outcomes for the community. An important lesson from the adaptive cycle involves its "memory" and "recombinant" qualities. Adaptive cycles may be nested in hierarchies through time and space (becoming tools for looking at cross-scalar linkages like climate, economics, or policy). Recombination comes from the ability of system agents to harness stored or released capital, testing their new configurations over time. These windows of experimentation open briefly, but the results do not trigger cascading instabilities of the whole because of the stabilizing nature of nested hierarchies. In essence, larger and slower components of the hierarchy provide the memory of the past and of the distant to allow recovery of smaller and faster adaptive cycles. A nested hierarchy of adaptive cycles represents what researchers beginning with Holling (2001) have termed "panarchy." Whereas hierarchical systems are influenced by broad, slow features constraining (or influencing) fast ones beneath them, panarchical systems may have both top-down and bottom-up, features interacting through slow and fast variables (Walker et al. 2006: 13).

The adaptive cycle points to the instability of ecosystems (and by extension, social ecological systems). Instead of a gradual build up of r-strategists to K-strategists as the traditional view of successional series posits, the entire system may go through sudden flips that move into omega (release) and alpha (reorganization) phases. This jibes well with the idea of multiple stable states that may transform down particular pathways or flip once a threshold is crossed. The latter flips are mediated by changes in slow variables (connectedness for example) that then suddenly trigger a fast-variable response or escape (Holling and Gunderson 2002: 35).

The case study of San Lázaro seems to illustrate that one of these slower variables, namely climate, is mediating a series of cascading changes in the economics and society of the region and its small holder families. Technology, the means to stepping out of the Ω-phase of destruction and into the α-phase of invention, experimentation and innovation has not come to the rescue of the transformation. Desert constraints continue and will continue to dominate ranching. As Nathan Sayre (1999: 205-206) concludes:

> *Millions of Dollars of public research, government support and ranchers' investments have aspired to control the natural processes upon which cattle reproduction and growth depend, but it cannot be concluded that they have succeeded. The pastoralist basis of range livestock production—reliance upon nature to do the value-producing work—has stubbornly refused to submit to technological manipulation…It is time to acknowledge that dominating the range through scientific-technical manipulation has failed, and that improvement in range conditions will only be realized by embracing, rather than eliminating, the pastoralist element of ranch production.*

Walker and others in the Resilience Alliance have optimistically speculated that social-ecological systems are sometimes able to "transform" themselves when agents recognize a system is untenable for some reason (Walker et al. 2004: 5). In contrast to adaptation, transformation adds new variables and releases others. The transformation of livelihoods from one type to another is a good example while an adaptation involves augmentation of existing livelihoods. In all cases, transformation adds another state (or multiple states available, while impacting multiple scales of the panarchy). Another example of transformation could be the replacement of ranching with wildlife conservation areas by consolidating pastures and removing cattle (rather than replacing cattle with another livestock type). Innovation inspired by the close working relationship between Group Five and the Sonoran Institute is an example of the positive transformations possible here. Unfortunately, the general level of disorganization throughout the community continues to prohibit more of these types of panarchical relationships from appearing within the community. The establishment of the grass seed banks too, points to the ecological resiliency of the grasslands and oak woodlands if sufficient biomass is retained or biophysical constraints can be lifted (such as herbivory).

Prognosticating the Future for San Lázaro

San Lázaro and its ejido have always been at the mercy of shifting political and economic poles. These poles have moved between Mexico City, Hermosillo, Cananea, and Washington, D.C. Unlike previous periods of recent history, the control of the ejido's resources—its landscape of productive upland ecosystems, fickle water sources, and biologically rich bottomland riparian areas are up for grabs now in this new political economic environment. Outsiders with money and resources have moved in, and may be there to stay, while the most original residents have shifted focus into new, more lucrative activities that reward the risk-takers with severe punishment or financial bonanza.

At the same time, government resources have been realigned by neoliberal architects in the capitals of Hermosillo, Mexico City, and Washington, D.C. The replacements to these programs of rural support and development are more closely tied to re-centered individualized risk within the community, household or individual operator. With the withdrawal of support another new resource entered the community: the Sonoran Institute. With its scientific resources, grant making skills, and matching funds, the NGO has presented the community some new opportunities to adapt a role in the binational watershed. How long the NGO and its representatives can maintain the connection is cause for concern, given that SI depends upon U.S.-based philanthropy and not government funds (which may be no more secure in a time of war and wealth concentration).

The new narcotic-funded elites of the community are also subject to change and reassignment, particularly as the United States and Mexico grapple with the formers strong desire to increase border security. And while the majority of community members may not outwardly support the narcotics trafficking through the area, the financial resources it brings to bear are substantial and, no doubt, addictive in the long run. I cannot speculate how long the community will tolerate the other, less savory aspects of the drug trade in the community—particularly as the traffickers increasingly pay for services with small quantities of narcotics rather than with cash. But it is most important to acknowledge here that the narcoeconomy, while entirely covert and difficult to discuss openly, sustains significant portions of the community that cannot be sustained otherwise by risky, privatized agropastoralism in a highly variable economic and biophysical environment.

The binational character of the watershed is more important than just as a corridor for smuggled goods and services. Because the Santa Cruz River crosses the border into Mexico, is utilized and then returns to the United States after 51 kilometers, it is subject of intense scrutiny as a binational water resource. As we have explored throughout this dissertation, water is the limiting factor for life in the watershed, but it is more than just another environmental variable in the ecological equation. Water scarcity, after all is a product of social systems as much as it can be the product of climatological, hydrological or demographics. Upstream from San Lázaro, the mostly uninhabited San Rafael Valley provides a relatively untapped headwater for the Santa Cruz, but one that is quickly exploited once it reaches the farmers of Santa Cruz. Pumping in the summer already impacts baseflows in the San Lázaro reach. Downstream, the long straw of the industrial border town of Nogales, Sonora alters the river's stream flow much more significantly—reducing its flows to ephemeral. As the city of 300,000 continues to absorb migrants from the interior, its drive to extract water from the watershed may increase, putting San Lázaro's now marketable water in its sights. This has the potential to explicitly highlight the inequities in how Mexican society addresses the uneven development of urban, industrial areas and rural agricultural ones. As Barbara Rose Johnston and John Donahue (*ibid*: 3) accurately note:

> *The quest to capture, store, and distribute a reliable supply of water (or energy) implies the capture of a commons resource and the building of structures and institutions to enclose, commodify, and control it. This process of politicizing and commodifying nature requires centralized institutions of power and a reliance on technology to conquer natural forces. Systems for controlling resource access and use*

typically reflect the ways in which society is organized and thus recreate and reproduce the inequities in society.

As the hundreds of smaller communities along the border expand demographically and their economic development accelerates under the globalizing regime of the North American Free Trade Agreement, water has become the single most important limiting resource (Ingram, Laney and Gillilan 1995; Mumme and Sprouse 1999). Water resources have long been a source of both conflict and cooperation in the border region, echoing the often contentious or ambivalent relationship between the United States and Mexico. Now that the region has moved from a peripheral one to a central staging area for hemispheric trade and economic development, the need to seek resolution for environmental conflicts and to develop new frameworks for appropriate understanding is absolutely vital (Berry 2000: 756). Whether San Lázaro has the tools to face the long reach of industrial *maquiladoras*, urban planners, and international trade is a matter of speculation at this point. But without real, long-term ecological and economic resilience at home, the community surely faces an uphill battle for survival.

APPENDIX A: Risk Survey Instrument

Risks in time and space

Going down list from part 1, ask the following of each:

1. En el año, ¿cuándo ocurre este problema?
2. En qualquier parte del año, ¿cuándo es este problema mas peligroso para la producción?
3. ¿Cuál es la estratégia para contrarrestrar este problema?
4. ¿Es mas facil a contrarrestrar este problema solo o con apoyo de otra gente?
    i. Si tienes apoyo, ¿quién te apoyan?

Prioritizing Risks

Vamos a dar prioridad a los riesgos.

1. ¿De toda estas amanazas (o riesgos), cuál es la mas importante para la producción en la milpa?

2. ¿Cuál es lo siguente en importancia?

3. ¿Cuál es de tercera importancia?

4. ¿Cuál es quinto en importancia?

5. ¿Cuál es sexto en importancia?

6. ¿Cuál es septimo en importancia?

7. ¿Cuál se octenta en importancia?

APPENDIX B: Community Survey

Buenos/as (días, tardes, noches). Me llamo ____________. Estamos participando en un censo de estudios comunitarios realizado por el Centro Comunitario de Conservación del río Santa Cruz y la Universidad de Arizona. Quisiéramos preguntarle sobre sus actividades agropecuarios en la comunidad, su uso de agua y suelo, su opinión del medio ambiente local, y sus datos demográficos. El proceso va a tardar aproximadamente media hora. Estos datos serán confidenciales y en un futuro presentaremos los resultados a la comunidad en el CCC. También la comunidad, el centro, y la Universidad de Arizona van a utilizar los datos agregados para diseñar programas de mejoramiento económico y ambiental en la comunidad. Si se siente incomodo con algunas de las preguntas, no tiene que contestarlas.

Datos Sociodemográficos y Socioeconómicos

1. ¿Cuántos años tiene Ud.? ________
2. ¿Cuántos años tiene Ud. viviendo aquí en San Lázaro? ________
3. Si viene de otra parte originalmente, ¿De donde viene, Ud.? _______________
4. ¿Dónde pasa la mayor parte del año?
   a. ¿en su rancho?
   b. ¿en este casa? San Lázaro
   c. ¿en otra parte?
5. ¿Es miembro del ejido? Sí □ No □ Si no, hay otra persona en la casa quién es? Sí □ No □
6. ¿En cual grupo está Ud.? _______
7. ¿Cuántos familiares o personas tiene Ud. viviendo en su casa? ________
8. Favor de decir la edad, el sexo y relación familiar de cada miembro de su casa.

Edad	Sexo	Relación familiar
62	F	Hermana (Ejemplo)

9. ¿Cuáles son sus fuentes económicas más importantes? (Se puede indica mas que una respuesta.)
   a. ¿sus vacas? Sí □ No □
   b. ¿su milpa o milpas? Sí □ No □
   c. ¿trabajo jornalero en otra parte? Sí □ No □
   d. ¿trabajo jornalero en la comunidad? Sí □ No □
   e. ¿dínero de pariente o parientes en los estados unidos? Sí □ No □
   f. ¿asistencía del gobierno? Sí □ No □
   g. ¿tienda comercial? Sí □ No □
   h. ¿carpintero, mecánico, o otra? Sí □ No □
10. ¿Cuál es lo más importante? (Ponga asterisco después del trabajo que se indica.)

11. ¿Tiene Ud. suficiente ingresos todos los meses? Sí □ No □
   a. ¿Si no, cuándo? (circule uno)

enero	febrero	marzo	Abril	Mayo	Junio
julio	agosto	septiembre	Octubre	Noviembre	Diciembre

Datos Agropecuarios

12. ¿Tiene Ud. milpa en la zona agrícola? Sí □ No □
13. Si no tiene, ¿Hay alguien en la casa quien cultiva algo en la zona? (Si no, salta hasta número 24)
14. ¿Cuántas hectáreas tiene en la zona agrícola?
   ____
15. ¿Sembró algo el año pasado? Sí □ No □
16. ¿Renta terrenos en la zona agrícola? Sí □ No □
17. Si, ¿Cuántas hectáreas renta? ___________
18. ¿Alquila sus terrenos a otra persona(s)? Sí □ No □
19. Si, ¿Cuántas hectáreas alquila?___________
20. ¿Cuáles son sus cultivos principales?
   a. maíz Sí □ No □
   b. frijol Sí □ No □
   c. chiles Sí □ No □
   d. alfalfa Sí □ No □
   e. sorgo Sí □ No □
   f. cilantro Sí □ No □
   g. ajo Sí □ No □
   h. cebolla Sí □ No □

i. árboles frutales de típo Sí □ No □ cuales_____________
j. zacate pasto Sí □ No □
k. otro ___________________ Sí □ No □

21. ¿De todos cultivos, cuál es lo más importante? (Ponga asterisco después de cultivo que se indica.)
22. Si cultiva su milpa en la zona agrícola, ¿Usa Ud. riego de:
    a. canal? Sí □ No □
    b. las lluvias? Sí □ No □
    c. pozo? Sí □ No □

    ¿Cuál es la fuente de agua más importante para su milpa? (Ponga asterisco después de la fuente que se indica.)
23. ¿Tiene Ud. (o alguien en su casa) bovinos en Miguel Hidalgo? Sí □ No □ (Si se responde no, salta hasta pregunta 30.)
    a. ¿Tiene Ud. más de 25 cabezas? Sí □ No □ (Si se responde no, salta hasta pregunta 25.)
    b. ¿Tiene Ud. más de 50 cabezas? Sí □ No □
    c. ¿Tiene Ud. más de 100 cabezas? Sí □ No □
    d. ¿Tiene Ud. más de 200 cabezas? Sí □ No □
24. ¿Cuáles potreros usan Ud. (generalmente)? ____
25. ¿Mata sus animales para comer? Sí □ No □ (Si se responde no, salta hasta pregunta 30.)
26. ¿Cuándo fue la última vez? __________________________ (mes o época)
27. ¿Comparte la carne con otra gente? Sí □ No □
28. ¿Con cuántas personas? _________________________
29. ¿Mata sus animales el año pasado por debilidad o enfermedad de los mismos? Sí □ No □
    a. Si los mató, ¿Cuántos? ______________________
    b. ¿Porqué los mató?____ ____
30. Si no tiene bovinos ahora, ¿Los tuvo en el pasado? Sí □ No □
31. Si los ha tenido, ¿Cundo fue la ultima vez? _____________________
32. Si no tiene bovinos ahora, ¿Vendió su derecho del uso del agostadero? Sí □ No □
    a. ¿Cuándo vendió el derecho (año)? ______________________
33. Si no tiene bovinos ahora, ¿Alquila su derecho a otra persona? Sí □ No □
    a. ¿Cuándo alquiló su derecho a otra persona (el año)? ______________________

Medio Ambiente

34. ¿Qué lugar en el Ejido o la comunidad le gusta mas? ¿Dónde está y porqué?
____
____

35. ¿Cuál es el lugar que mas le gusta del Río Santa Cruz? ¿Dónde está y porqué?
____
____

36. ¿Cree que el uso urbano (Nogales) afecta las corrientes del río? Sí □ No □ ¿Cómo? ______________________

37. ¿Cuáles son los efectos del bombeo y riego en las corrientes del río?
____
____

38. ¿Cuál crees que sea el futuro del río? ____

39. ¿Que efectos esto puede tener en la comunidad?
____
____

40. ¿Cuándo fue la ultima vez que nevó en el pueblo de San Lázaro? ______________________________

41. ¿Cuándo fue la ultima vez que creció el río en San Lázaro? __________________________________

42. ¿Cuándo fue la ultima vez que llueve en el invierno suficiente para hacer verde el pasto hasta mayo?
____

43. Normalmente, cree que el río tiene suficiente agua en
   a. el invierno Sí □ No □
   b. la primavera Sí □ No □
   c. el verano Sí □ No □
   d. el otoño Sí □ No □

44. Normalmente, cree que cae suficiente lluvia en
   a. el invierno Sí □ No □
   b. la primavera Sí □ No □
   c. el verano Sí □ No □
   d. el otoño Sí □ No □

45. ¿Cuándo llueve en su rancho o potrero preferido, el agua corre o se queda estancada?
   a. Corre Sí □ No □
   b. Se queda Sí □ No □

46. ¿Cuál es su estrategia para contrarrestar la sequía?
   a. Mata los animales débiles Sí □ No □
   b. Vende sus animales o algunos de ellos? Sí □ No □
   c. Compra pacas de forraje Sí □ No □
   d. Mueve sus animales a otro potrero mejor (si hay) Sí □ No □
   e. No hace nada Sí □ No □
   f. Otra estrategia ____

47. Comentarios, notas u observaciones: ______________________________________

____

____

48. ¿Tomamos su fóto? Sí □ No □ Si se indica "sí", nota número (u números) de fóto(s) aquí: _____________.

49. Sí hay mas preguntas, ¿Podría visitarle otra vez y preguntarle más? Sí □ No □

¡Muchas gracias para su información!

Río Santa Cruz
San Lázaro

Appendix C: North American Beef Prices 1980-2006

Average Prices

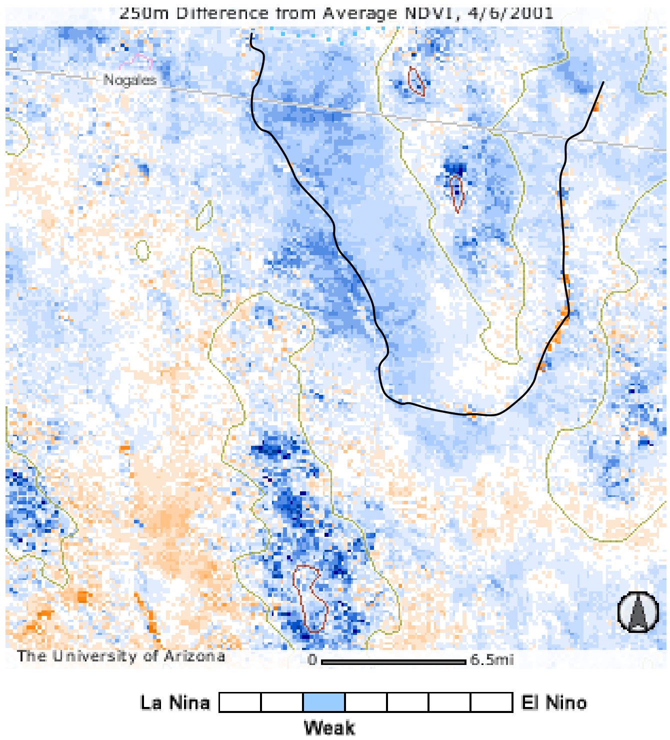
Cattle, Wholesale Beef, and Retail Beef

Year	Choice Fed Steers*	Choice 650 lb Feeder Steers*	Choice 450 lb Steer Calves*	Light Choice Beef Cut-Out Value	Choice Retail Beef	All Retail Beef	Featured Retail Beef
	$/cwt	$/cwt	$/cwt	$/cwt	$/lb.	$/lb.	$/lb.
1980	67.97	73.11	84.62	104.44	2.34	N/A	2.31
1981	65.05	64.40	70.80	99.88	2.35	N/A	N/A
1982	65.22	63.32	67.93	101.31	2.38	N/A	2.25
1983	63.66	62.71	69.30	97.83	2.34	N/A	N/A
1984	66.31	64.11	69.88	100.11	2.35	N/A	2.13
1985	60.05	63.03	71.32	90.76	2.29	N/A	2.05
1986	58.93	60.52	69.01	88.98	2.27	N/A	2.05
1987	66.14	73.82	84.73	97.21	2.38	2.13	2.16
1988	70.93	82.71	96.47	103.28	2.50	2.25	2.26
1989	73.94	84.14	98.76	107.78	2.66	2.46	2.41
1990	78.32	89.02	103.22	116.54	2.81	2.62	2.56
1991	74.28	90.72	105.69	118.31	2.88	2.71	2.62
1992	75.27	83.98	96.77	116.65	2.85	2.66	2.56
1993	76.40	88.96	103.15	119.23	2.93	2.71	2.72
1994	69.29	80.05	93.42	108.57	2.83	2.65	2.59
1995	66.57	68.21	78.22	106.62	2.84	2.59	2.42
1996	65.00	59.22	64.10	102.87	2.80	2.52	2.45
1997	66.09	78.22	88.88	103.00	2.80	2.54	2.50
1998	61.73	75.32	87.5	99.73	2.77	2.53	2.52
1999	65.65	78.63	92.92	110.99	2.88	2.61	2.58
2000	69.65	91.91	109.12	115.33	3.06	2.75	2.72
2001	72.29	92.65	110.65	123.17	3.38	3.01	2.93
2002	67.46	79.22	100.90	114.95	3.32	3.05	2.85
2003	83.72	92.75	109.55	143.75	3.58	3.31	N/A
2004	84.54	110.61	129.95	141.86	4.06	3.61	N/A
2005	87.75	117.73	140.06	145.01	4.09	3.64	n/a

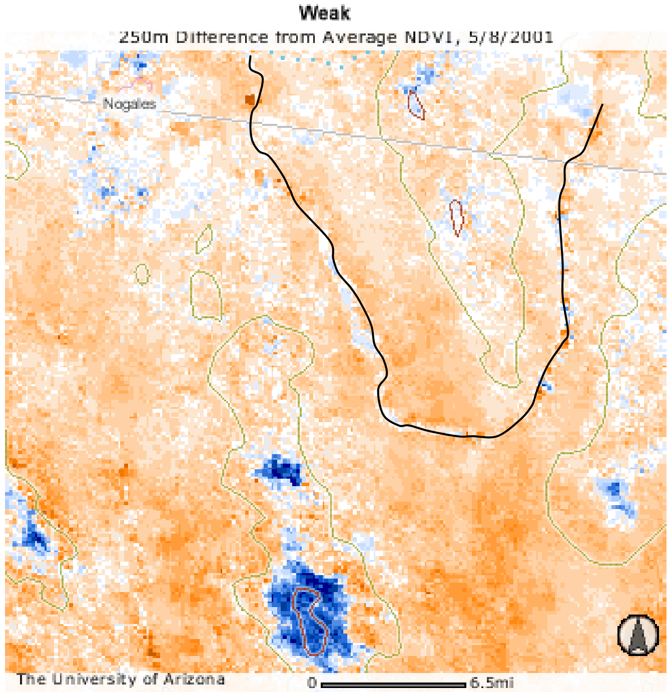
* Cattle-Fax Averages

Sources: USDA, Cattle-Fax and National Cattlemen's Beef Association, http://www.beefusa.org/newsindustrystatistics.aspx

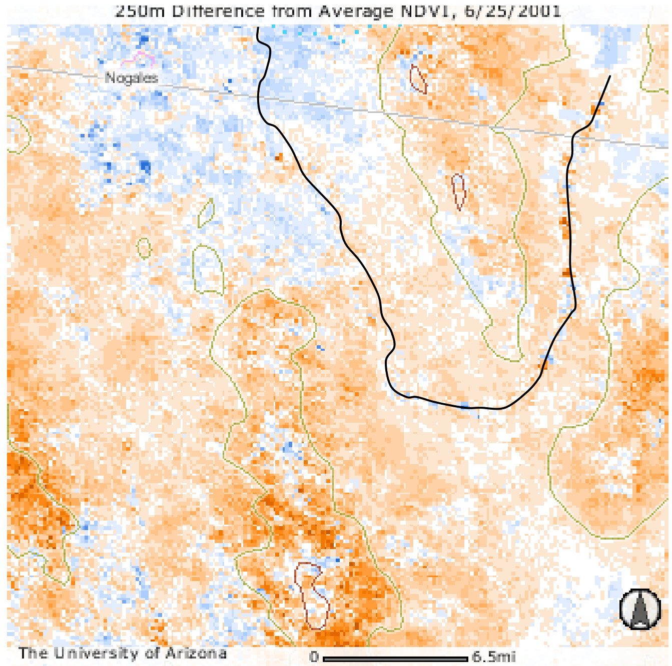
APPENDIX D: SEASONAL DIFFERENCE IN VEGETATION COVER (NDVI) IN THE UPPER WATERSHED



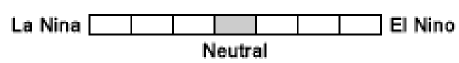
A

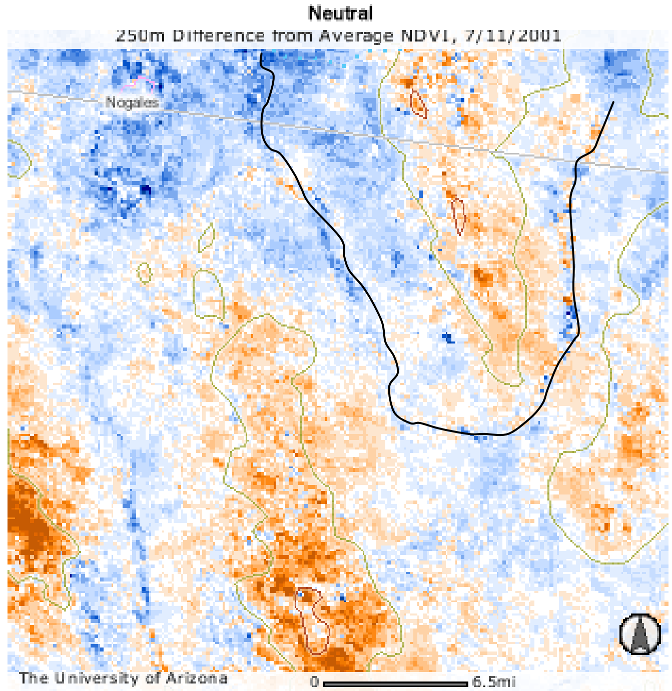


B

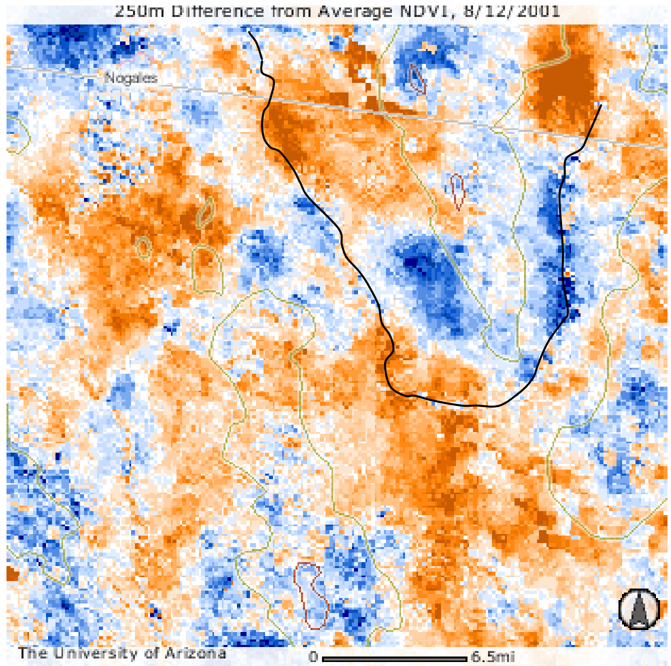

250m Difference from Average NDVI, 6/25/2001
Nogales
The University of Arizona
0
6.5mi

C


La Nina
El Nino
Neutral

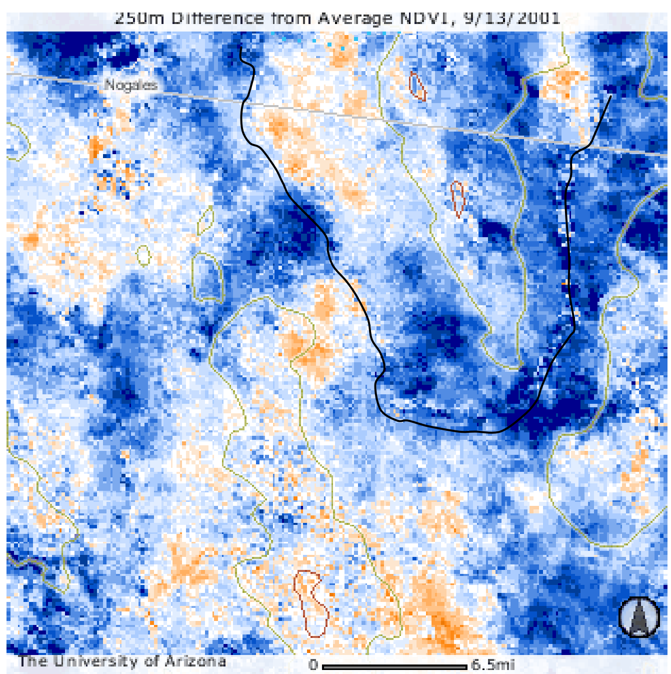

250m Difference from Average NDVI, 7/11/2001
Nogales
The University of Arizona
0
6.5mi

D

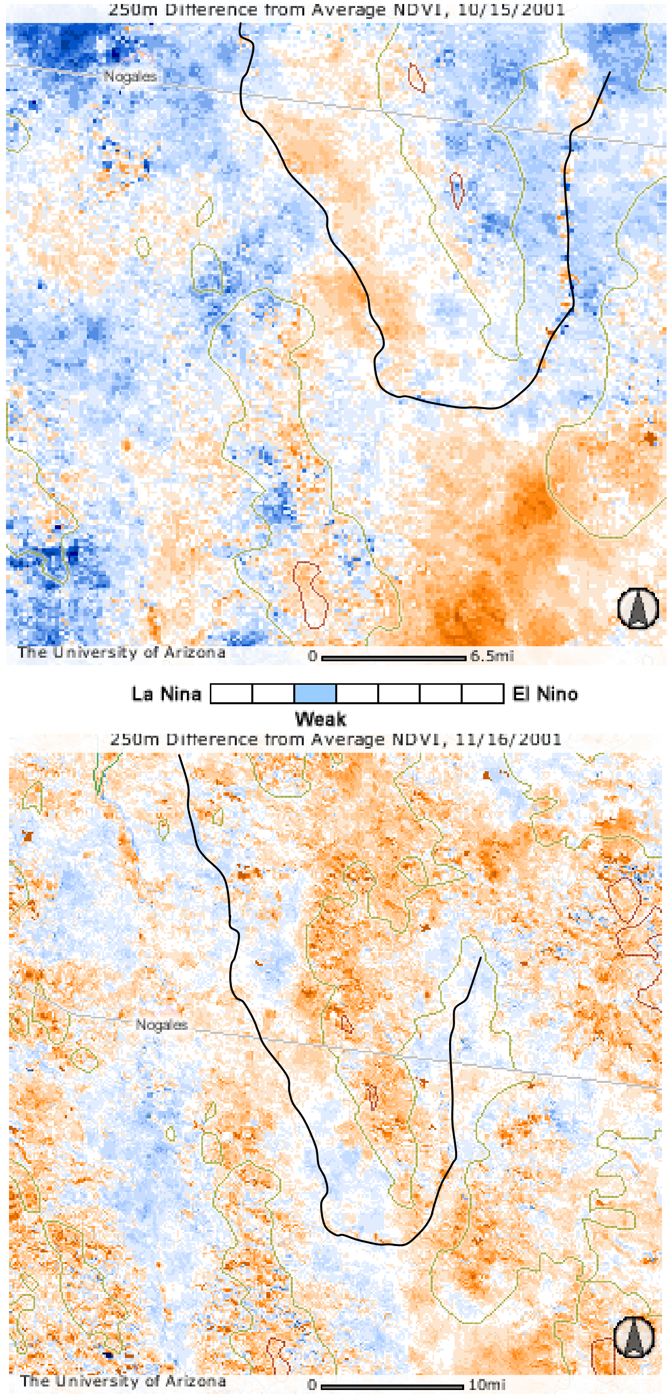


E

La Nina Neutral El Nino



F



G

H

Normalized Difference Vegetation Index (NDVI); calculated by subtracting near infrared from red spectral band/divided by the same two terms summed. Source: Arizona RangeView program: (http://rangeview.arizona.edu). Blue signifies dimished cover.

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