LINKING LAND CHANGE AND COMMODITY CHAINS IN A GLOBALIZING WORLD: THE CASE OF MEXICO

By

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ABSTRACT

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Global land change continues to concern both scholars and the general public. Loss of tropical forest, in particular, creates significant impacts with respect to biodiversity resources and the carbon cycle. Recently, researchers have grown hopeful that countervailing processes of forest recovery, often referred to as forest transition, will mitigate environmental damage imposed by forest loss. The UN's REDD program has served to focus attention on how to reduce deforestation and encourage forest transitions. Such policy initiatives are praiseworthy, but their ultimate success depends on uncovering the underlying drivers of land change (LC), whether forest loss or gain. Adding complexity to the policy debate are the far-reaching impacts of globalization. The dissertation seeks to add to our understanding in this regard by undertaking a national-scale study aimed at comprehending how globalization affects LC processes. Specifically, the dissertation links broad shifts in national LC dynamics with spatial shifts or re-territorialization of food commodity chains, in the context of neoliberal reform affecting a domestic economy. It addresses the combined issues of forest loss and forest gain as they occur within the borders of an individual nation by assessing the changing territorial imprints of beef cattle and maize (M&B) production in Mexico. Agricultural change often drives LC, so it should come as no surprise that substantial research identifies M&B production as a proximate cause of Mexican LC. However, this research goes a step further and embeds this proximate causation within the broader social structures from which it originates, namely those associated with globalized commodity chains. In doing so, the project's novel approach addresses LC through constructs drawn from Economic Geography. Two research hypotheses are advanced: (1) that the production geography of M&B commodity chains shifts over time, triggered by neoliberal reform, and (2) that shifts in source regions for both commodities explain patterns of land change across Mexico, with some areas experiencing forest transition and others deforestation. The dissertation employs a mixed methodological approach to address these hypotheses, including formal and informal interviews with firms and key informants, field observations, and spatial econometrics using land use data from agricultural census and national land cover data for the years 1991 and 2007. My results suggest that neoliberal reform is redefining M&B production geography. The rise of the Mexican feedlot and the maize flour industry are closely related to the adoption of free trade policies and transfer of prior governmental functions in the food sector to private agents. The dissertation shows that the spatial changes of the beef component of the M&B commodity network correspond in many ways to changes in forest cover. When herds diminish, there is FT; when herds expand, forests are lost. The econometric analysis confirms this pattern. Deforestation in Mexico continues to slow down, in part, with the help of large volumes of corn imports from the US and cattle smuggled from Central America.

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KEY TO ABBREVIATIONS

ALMER	Almacenadora Mercader
AMEG	Asociación Nacional de Engordadores de Ganado
AMPAS	Asociación Mexicana de Producción Animal y Seguridad Alimentaria, A.C
ANDSA	Almacenes Nacionales de Depósito S.A.
ANSA	Almacenes Nacionales S.A.
ANTAD	Asociación Nacional de Tiendas de Autoservicio y Departamentales
ASERCA	Agencia de Servicios a la Comercialización y Desarrollo de Mercados Agropecuarios
BSE	Beef Spongiform Encephalopathy
BURUCONSA	Bodegas Rurales CONASUPO S.A.
CBOT	Chicago Board of Trade
CONASUPO	Compañía Nacional de Subsistencias Populares S.A.
CNOG	Confederación Nacional de Organizaciones Ganaderas
DICONSA	Distribuidora CONASUPO S.A
ESDA	Exploratory Spatial Data Analysis
FERTIMEX	Guanos y Fertilizantes de México S.A
FMD	Foot and Mouth Disease
FT	Forest Transitions
GATT	General Agreement on Trade and Tariffs
GCC	Global Commodity Chains
GRUMA	Grupo MASECA
ICONSA	Industrias CONASUPO S.A.
INEGI	Instituto Nacional de Geografía y Estadística
ISI	Import Substitution Industrialization

LC	Land Change
LCR	Land Change Regime
LISA	Local Indicator of Spatial Association
LSS	Land System Science
MA	Mexican Altiplano
MICONSA	Maíz Industrializado CONASUPO S.A.
MT	Metric Tones
NAFTA	North American Free Trade Agreement
NVA	Neovolcanic Axis
OCETIF	Organismo de Certificación de Establecimientos Tipo Inspección Federal (TIF)
OECD	Organization for Economic Cooperation and Development
PAC	Programa de Agricultura por Contrato
PROCAMPO	Programa de Apoyos Directos al Campo
SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural y Pesca
SAR	Spatial Autoregressive Model
SDM	Spatial Durbin Model
SEDARPA	Secretaría de Desarrollo Rural y Agrícola y Pecuario (Veracruz)
SEM	Spatial Error Model
SENASICA	Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria
SIAP	Servicio de Información Agroalimentaria y Pesquera
SMO	Sierra Madre Occidental
SMS	Sierra Madre del Sur
SON	Sierra Norte de Oaxaca
SOR	Sierra Madre Oriental
USDA	United States Department of Agriculture

1. INTRODUCTION

Conversion of native forest to human-induced covers is one of the most important and pressing processes of the current global environmental crisis. Forest destruction accounts for 38% of the carbon emissions from agriculture and forestry, a sector that contributes nearly one-fourth of the global emissions of greenhouse gasses (Tubiello et al. 2014). Deforestation and forest degradation are the primary drivers of species extinction and biodiversity loss in terrestrial ecosystems (Sala et al. 2000). Millions of people—especially the most vulnerable populations, rely on the resources and services provided by forest ecosystems (Sunderlin et al. 2008). Changes in land use and land cover are associated with land degradation, including soil erosion and desertification, which may induce chronic poverty and deterioration of natural assets (Millennium Ecosystem Assessment 2005). Measuring the transformation of the Earth surface and understanding its proximate and underlying causes, particularly since the launching of the Landsat program by NASA in 1972, has been established as a major research area within Geography and Environmental Sciences. Today, this important interdisciplinary field is known as Land Change Science or Land Systems Science—LSS (Gutman et al. 2004; Turner, Lambin, and Reenberg 2007).

LSS has evolved dramatically over the past several decades. Both empirical research and actual applications to modeling have grown in sophistication, thanks in large part to computational power and data availability, particularly associated with remote sensing platforms. Despite these advances, theory has moved more slowly, in which case the science as a whole stands poised for conceptual innovation. A sense to cross-fertilize LSS with other fields is growing within the scientific community (Turner and Robbins 2008; Seto et al. 2012; Brannstrom and Vadjunec 2013; Munroe et al. 2014), motivated by the recognition of the new challenges imposed by globalizing phenomena to understand land systems. In this regard, LSS faces three main challenges. First, it needs to put more attention on underlying processes driving land allocation decisions. The tropical agriculturalist household has been a favorite subject in search of explanations of land change (LC), and much research has focused on analyzing and modeling the behavior of individual households from social, anthropologic, and economic standpoints. This perspective is clearly useful because it focuses on the most direct agents of change; however, it is also incomplete. LC is a complex process resulting from decisions and interaction of a myriad of factors across multiple scales. Households are just the last echelon in a long chain of causality or explanation (Blaikie and Brookfield 1987). Moreover, the context in which smallholder agriculture unfolds is also rapidly changing. The colonist smallholder is being superseded by agribusiness and corporations as proximate agents of deforestation (Rudel et al. 2009), while their decisions are increasingly bounded by corporate control mechanisms such as contract farming and private standards. In the global tropics, farmers are increasingly linked to transnational labor markets that constrain land allocation decisions or infuse capital and information that boost changes in local land use patterns. New capital inflows from national and multinational companies, new systems of provision for agricultural products, shifting consumer preferences, new quality and safety standards, among other factors, are dramatically changing the conditions for the development of agriculture—and thus LC, in developing countries. LSS needs to be able to incorporate this complexity, in particular, LSS should be able to address LC as the outcome of multiple interacting agents and interdependent processes constituting socio-spatial structures.

Second, LSS has given preference to “high-resolution approaches,” that is, research with an emphasis on processes occurring within restricted spatiotemporal frames –often spanning only a few square kilometers and few years. Partly, this is a consequence of preference on detailed behavioral studies at the household level, which often default to cross-sectional analysis of small study areas for obvious practical limitations –constrained, for example by the cost and availability of remotely sensed data at high spatial and temporal resolutions and long-term research periods. Clearly, high-resolution approaches provide rich detail on proximate causation within the limits of the region, but limited insights on complex inter-regional LC dynamics occurring, for example, within the boundaries of a nation-state. One problem with this is that LC dynamics are contingent on the chosen spatiotemporal scale (Walker 2010), and extrapolating conclusions from one scale to another is problematic. There are, however, some relevant efforts. Forest transition (FT) studies (Mather 1992; Walker 1993; Grainger 1995b), at least in their original intent, represent a push to build upon general historical trajectories of national LC. Grainger’s “National Land Use Morphology” (Grainger 1995a) inspired in Sauer’s Morphology of Landscape (Sauer 1925), is an attempt to understand national land use dynamics as an attribute of an evolving cultural landscape. Nevertheless, this trend did not last long, as attempts to generalize core FT concepts to tropical deforestation in developed countries met with harsh criticism (Robbins and Fraser 2003; Perz 2007; García-Barrios et al. 2009). While research on FT remains relevant for LSS, the interest has focused again on fine grain research.

Finally, LSS literature has focused on individual LC trajectories, e.g. deforestation or forest transitions, often assuming change processes are determined endogenously. For example, one source of criticism on FT studies is that this literature overlooks spatial interdependence in LC dynamics; the possibility that one region’s FT is another region’s deforestation (Pfaff and Walker

2010). With respect to forest cover, trees may be slashed and burned in deforestation operations, while forest seeds can sprout on abandoned land, laying the foundation for forest recovery (or forest transition) in agricultural areas. Clearly, the scale again is important. Deforestation and FT may seem unrelated at the scale of the rural household, but looking at broader spatiotemporal scales, we may find that, in fact, both are outcomes of the same process.

Recognizing the challenges listed above, LC scientists are beginning to incorporate new concepts and frameworks. The commodity chain construct (also called supply chain or production network) is increasingly applied in the LSS literature as a conceptual tool to link proximate causation with processes that occur beyond the limits of the atomistic household. These studies draw attention to two key dimensions of the commodity chain, one focusing on a normative side stressing chain governance and another on the analytical capabilities of this concept to articulate cross-sectoral and cross-scalar phenomena. For instance, Nepstad et al. (2014) and Gibbs et al. (2015) stress the role of supply chain governance schemes from large soybean buyers in halting deforestation rates in the Brazilian Amazon. Because such buyers exert a high degree of control over upstream producers in the supply chain, they can monitor and enforce the Soy Moratorium, a zero-deforestation agreement signed by agribusiness. In addition, large transnational corporations are willing to participate in programs that improve their image as green businesses. On the other hand, Seto et al. (2012 p. 7691) suggest that the chain concept may be useful in shedding light on the complex interactions and energy and material flows associated with urban land teleconnections. Specifically, they argue, the chain construct can link "actors (e.g., households, institutions, and firms), processes, and places of production and consumption." In a more ambitious statement, Munroe et al. (2014) advocate commodity chain research as a way to "reinvigorate" LSS by offering a relational perspective as an alternative to the dominant neoclassical paradigm. Munroe and coworkers also contend that the chain construct can provide new insights to understand land "teleconnections" in an era of increasing transnational integration.

The dissertation considers the evolving organization of agri-food production to explain LC at the scale of the nation-state. An important premise is that the nation constitutes a key scale of analysis to articulate inter-regional processes with trans-boundary phenomena. However, the interest is not in the nation as a bounded territory, but as a level of organization displaying coordinated agency and a definite socio-spatial structure. Specifically, the case of the evolution of Mexico's maize and beef (M&B) commodity chains following neoliberal reform is considered. Here, the commodity chain embodies a particular division of labor, the set of activities involved in production (including design), delivery, and consumption of M&B. Any activity requires agency, coordination, and a place for it to occur. M&B commodity chains, as well, encompass multiple agents coordinated across different economic sectors and across different places of production and consumption. Commodity chains are constantly evolving; as the socioeconomic, technical, and environmental conditions change, and so does their coordination and spatial structure. LC occurs during cycles of expansion and contraction of production (and consumption). For example, deforestation may result from the incorporation of new cropland or pasture areas; forest transitions may result when those same places are disarticulated from M&B chains.

As it turns out, Mexico presents a useful case for this research for three reasons. First, Mexico shows important cross-border phenomena, both in the delivery of commodities to market (Mexican beef to US consumers and *vice versa*; US maize to Mexican feedlots) and in the sourcing of primary inputs (Mexican fattening calves from Guatemala and Nicaragua). In the 1990s, Mexico transitioned from a closed economy to one of the most open countries in the world. Second, it reveals complex LC dynamics, with some parts of the country experiencing forest loss and other parts, forest transition. Finally, data availability makes it possible to consider LC processes in periods both before and after neoliberal reform, starting with Mexico's admission to the General Agreement on Trade and Tariffs (GATT) in 1986, and culminating in the North American Free Trade Agreement (NAFTA), effective on January 1, 1994. NAFTA substantially opened the Mexican economy to foreign investment and trade and formed part of a process of economic restructuring, including both privatization of the *ejido* commons (Smith et al. 2009) and state retraction from direct intervention in the economy. Thus, NAFTA and the privatization of once-communal lands reveal twin facets of Mexico's emergent neoliberalism.

No other commodities are as suited to this research as M&B. It is a fair approximation to say that M&B chains have national territorial reach. Combined, M&B production involves more than 2/3 of the population engaged in agriculture and a similar fraction of the national continental territory. Both activities are strongly embedded in the social matrix and have deep cultural and historical roots. They represent contrasting symbols of class struggle and convey opposing views about neoliberalism. Cattle ranching evokes power and the success of the colonization process. The rise of the beef industry and its increasing presence in global markets are viewed as signs of the triumph of neoliberal policies and globalization. On the other hand, maize typically symbolizes the resilient peasant household and its indigenous heritage. Maize is a symbol of national identity and opposition to the neoliberal project. The national coalition "Sin Maíz no Hay País" exemplifies this view. Thus, by studying the evolution of M&B commodity chains, we can observe a radiography of a changing society, as it adopts a new regime of capital accumulation. LC occur as national landscapes are re-accommodated to new socio-spatial relations of production.

Once a deforestation hotspot and now considered a candidate for forest transition (Rudel, Bates, and Machinguiashi 2002), Mexico has attracted substantial interest from the LSS community. Amidst the drastic and fast-track policy reforms undertaken by the Mexican government during the 1990s, researchers have found in this country a natural laboratory in which to explore the relationship between economic development and the environment. Notorious are the studies by Grossman and Krueger (1991, 1994), which became foundational for the Ecological Modernization literature (Ehrhardt-Martinez, Crenshaw, and Jenkins 2002). Although Grossman and Krueger focused on pollutants, much of the forest transition literature embraced similar research methods and arguments. In addition, a considerable amount of research addresses the effects of neoliberal reform on themes such as welfare and rural livelihoods of small-scale producers, food security, and agrobiodiversity loss (e.g. Brush 1995; de Janvry, Sadoulet, and de Anda 1995; Nadal 2000; Yúñez-Naude and Barceinas 2002; Perales, Benz, and Brush 2005).

Within the LSS literature, however, few studies delve into the linkages with the agri-food sector, which is undergoing rapid expansion and transformation in the current neoliberal period and is increasingly shaping agricultural production and policies. Transformation of Mexico's beef industry, in particular the rise of the feedlot sector, and its linkages with domestic and international grain markets has been largely ignored, not only by US LC scholars but also by leading Mexican economists and sociologists. This neglect may be explained by the strong emphasis scholars have placed on smallholder agriculture in search of causal explanations for LC. As a consequence, most of our knowledge within this field is on smallholder-driven landscape dynamics. Moreover, despite the large volumes of literature analyzing and describing what is generally perceived as the crisis of Mexico's agricultural sector, there is still little work on the other side of the story—the rise of agribusiness.

Summarizing, LSS still needs to move beyond proximate causation. This requires articulating distal phenomena in LC explanations. Understanding how distal causes operate may require looking at scales that span beyond the limits of the region. The national level is proposed here as a starting point, but rather than a territorial unit, the nation is conceptualized as a level of organization. The commodity chain construct is employed to give concrete meaning to coordinated socio-spatial structures of production and to disentangle their roles in LC processes, considering deforestation and FT. This exercise is necessary because the body of literature linking commodity chains and land change is new and scarce. To my knowledge, there are no empirical applications that fully exploit the commodity chain theory or methods developed in the realm of economic geography. By using the chain construct, my dissertation aims to be useful in the following ways: (1) to understand how globalizing phenomena impact agriculture in Mexico and (2) to understand the land change consequences of inter-regional interactions in a country experiencing both deforestation and forest transitions. By so doing, the dissertation also aims to contribute to the discussions in the literature regarding the impact of economic development on LC, as well as the application of LSS to generate prescriptions to mitigate deforestation and climate change.

1.1 Dissertation hypotheses

Prior research suggests that neoliberal reform had considerable effects on Mexican agriculture. Most observers highlight how free trade policies and a reduction of social investment in the sector hard hit small producers, leading to massive withdrawal from primary production (Audley et al. 2004). The impact of these trends on forest transitions has already been noted by land change scientists (e.g. Klooster 2003; López et al. 2006). Over the last two decades, aggregate forest loss rates have declined in Mexico, inviting speculation on the possibilities of national forest transition in the near future. A scenario such as this would have important implications for a mega-diverse country historically assailed by environmental degradation (Simon 1997) and alarming rates of forest clearance. Yet, other researchers have raised concerns regarding the observed trends in Mexican agriculture (García-Barrios et al. 2009), stating that neoliberalism is a double-edged sword regarding its environmental impacts. In particular, as previous research suggests, while some producers have withdrawn from agriculture others have shifted to livestock production (mostly cattle ranching) and tree plantations that require additional forest clearing. Thus, Davis (2000) found that, after reforms, smallholders expanded cattle herds as a livelihood strategy to face declining agricultural prices. The same producers also expanded the area planted under maize, suggesting increasing reliance on this crop as feed and forage. Similar trends have been linked to deforestation in forest frontier areas (e.g. Busch and Vance 2011). Taken together, these findings suggest that the impact of neoliberal reform on LC has been uneven across space, with some regions experiencing forest cover expansion and others decline.

So far, the crisis of smallholder agriculture triggered by neoliberal reform is at the center of most explanations for observed LC trends in Mexico and elsewhere. Clearly, this is an important part, although—the researcher will argue—it provides only a partial explanation. The evolution of the agri-food sector in the neoliberal period, particularly the transformation of industries linked to maize and beef production, adds up to another important component explaining LC in Mexico. Neoliberal reform enabled factor mobility and lifted constraints for the expansion of the private sector. A new structure of food governance referred elsewhere as a "corporate food regime" (McMichael 2008) emerged, controlled by large multinationals and characterized by private regulation and increasing dependency on international trade. The first hypothesis advanced in the dissertation is that a new production geography of M&B has emerged in Mexico under what is referred here as the neoliberal food regime. Two interrelated land use dynamics shape the new spatial form: spatial concentration of maize production and capital intensification of beef production. The former is linked to the rise of the private sector, controlled by large corporations, as leading players in maize distribution and processing (in particular the milling industry). The rise of the Mexican feedlot and the so-called "supermarket revolution" are mainly responsible for the latter. Critical components of the new spatial configuration of M&B production involve a reliance on US imports of corn for animal feeding, a shift to irrigated production of maize for domestic *tortilla* consumption, and the outsourcing of calving operations to Central America.

The second hypothesis tested is that the spatial distribution of forest gain (forest transition) and loss (deforestation) across Mexico is largely explained by the new production geography of M&B, as considered in hypothesis 1 above. More specifically, land use changes related to regional processes of expansion and contraction of M&B production will explain to some extent changes in forest cover (forest transitions and deforestation).

The dissertation is organized as follows. Chapter 2 presents a review of relevant developments in the land change literature. The review focuses first on theoretical approaches and then on empirical applications in Latin America. Later, the chapter moves into the commodity chain literature and discusses its application in the context of land change research. Chapter 3 sets the biophysical and social-historical context for the Mexican case. The hypotheses advanced in the dissertation, and the methodology to address them are deployed in Chapter 4. Results and discussion are rendered in Chapter 5. Finally, conclusions are drawn in Chapter 6.

2. BACKGROUND

2.1 Conceptualizing land change

LC, or land use and land cover change, is the transformation of the Earth's land surface by human activity. While LC involves a broad class of alterations, much of the focus in LSS has been on topics such as deforestation, FT, and urbanization. LC entangles two components: land use, which refers to a specific human activity such as agriculture or forestry, and land cover, which is the physical component of the land visible from above. Both components are difficult to separate while describing a landscape, and land classifications often conflate them. For example, a typical classification distinguishes agriculture and forest cover. The former is a land use which encompasses a variety of land covers such as crops, fallow land, tillage, et cetera, while the latter is a land cover type which may include natural forest for recreational uses or planted trees for logging. For the dissertation, we will need to distinguish between the two components because testing the second research hypothesis requires establishing a direct causation link between specific land uses, i.e. maize cropping and cattle ranching, and Mexico’s forest cover change. This way of proceeding departs from standard practice in LSS, where both land use and land cover act as dependent variables, and socioeconomic factors are predictors or explanators. One advantage of direct causation is that we can focus on the dynamics of expansion and contraction of concrete commodities across different regions and assess its local impacts while momentarily foregoing local socioeconomic determinants. For instance, out-migration is a known driver of forest transitions, but it is part of a mechanism that involves agricultural abandonment. By focusing on land use, we can capture these change processes, although the specific local drivers triggering them are not observable. Instead, the researcher builds upon commodity chain research methods to assemble a causal explanation for observed spatial patterns of M&B land use change.

Presenting a full review of the vast literature on LC is beyond the scope of the dissertation. Rather, the literature review focusses on two theoretical approaches that epitomize two forms of explanation in LSS. In explaining LC, scientists recognize two broad categories of causal factors: proximate and distal, or underlying, causes (Turner 1989; Geist and Lambin 2001). If we conceptualize LC as the outcome of a series of chained processes, proximate drivers correspond to the most immediate phenomena in the chain of causality. Agriculture, logging, and road development are examples of proximate causes. Underlying or distal drivers are phenomena occurring farther apart in the chain of causality, influencing proximate drivers and indirectly inducing LC (Meyfroidt 2014). Economic growth, demographics, and trade policies are examples of underlying causes.

The bid rent model developed by von Thünen and widely applied in studies of tropical deforestation is the strongest theoretical statement on proximate causation (Walker 2004). Thünen's model offers a foundational theory of land use allocation by diminishing returns to distance and addresses the question of the comparative advantage of intensive (high capital) versus extensive (low capital) agricultural production (Krzymowski and Minneman 1928). In contrast, early literature on FT attempts to build a general theory based on underlying causes (Mather and Needle 1998). Here. the focus has been on general development paths or syndromes associated with large scale LC phenomena (Rudel et al. 2005). Although interest in FT now seems to dominate interest in deforestation, much LC theory addresses the latter process.

Despite the potency of von Thünen's seminal model and the appeal of FT to build onto general theories of LC, researchers are increasingly finding cause to broaden their conceptual frameworks to account for phenomena difficult to capture or inconsistent with these models (Walker 2004). Thus, the dissertation heeds calls (Munroe et al. 2014) to reinvigorate LC science with approaches from "New Economic Geography" that redirects attention from decentralized land managers to corporate actors, governance systems, the cultural embeddedness of economic activities, and globalized production and distribution networks (Robert-Nicoud 2004; Boschma and Frenken 2006; Hess and Yeung 2006; Marchionni 2006). The dissertation's conceptual framework does not follow the abstract modeling side as represented by Fujita and others (1999). Instead, it draws inspiration from political economy perspectives that interpret the world's food system as a global production and consumption network comprising webbed commodity chains that ultimately yield the food products critical to human subsistence. The following section discusses the bid rent paradigm and FT theory. A discussion of the commodity chain literature and its application to the Mexican context follows.

2.2 The bid rent paradigm and forest transition theory

2.2.1 The bid rent paradigm

The bid rent paradigm is grounded on von Thünen's *Isolated State* (von Thünen 1966) and is a theory of the conditions that lead to capital intensification of agricultural production. A key concept is the Ricardian notion of bid-rent. The basic model considers a world with a single central market surrounded by a flat country. There are no comparative advantages for production at any point, except for the relative position with respect to the market. The important outcome in this extremely simplified model is the spatial structure in the pattern of agricultural intensity. Both the value of the product and cost of production rise near the center, but at different rates. Cost of production increases at a lower rate because lower transportation costs compensate for more expensive goods and services near the city. Thus, near the city center, net revenues represent a larger proportion of the total value of production. At any point within the Isolated State, profit-maximizing agents will choose the degree of intensity with the highest revenue or rent (the best bid for a given unit of land). To better visualize the principle, consider the case of two production systems, A and B, shown in Figure 1. Produce from A (e.g. dairy) has better prices, but transport to the market O is also more expensive than produce from B (e.g. grazed beef cattle). Let m_1 be the bid-rent curve for A and m_2 the bid-rent curve for B, and $m_2 > m_1$. The intensive margin is OA, where m_2 and m_1 intersects. At this point, it makes no difference which system is chosen, but beyond OA, producing B becomes more profitable than producing A. The extensive margin is OB, where m_1 intersects the cost curve of B. This is the limit where production of B is no longer profitable. Within the intensive margin, the cost of production for A is higher than for B, but the ratio of net revenues to the total value of produce is higher for A than for B; thus, lands devoted to A represent the best option and the best bid.

With the basic Thünian model in place, it is straightforward to observe the implications of land rent for deforestation and FTs. In the Thünian model, land rents determine the degree of intensification and the succession of land uses, including forestry, from the central market to the extensive margin. For example, FTs result on stages where the balance of forces (the price conditions) shift against agriculture at the extensive margin, and in favor of forestry (Angelsen 2007; Barbier, Burgess, and Grainger 2009). These two theoretical possibilities are shown in Figures 1b and 1c. Figure 1b shows the effect of an increase in agricultural productivity (e.g. by improving fertilizing techniques); all other things being equal, increasing output per unit area causes a fall in the price of produce from p to p'. Because costs of production remain the same, the new equilibrium points will shift to A' and B'. Improving productivity will save a fraction of land in the extensive zone equal to B'-B. Consider now an increase in the value of forest, for example, due to scarcity of forest products and services. This shift may be strong enough to displace agriculture from the extensive zone and set forest in place, as shown in Figure 1c. This possibility is not an extreme one and is quite common in large cities in the US and Europe. It is interesting to note here that von Thünen himself included forestry in the second ring, just after the intensive margin, while extensive agricultural systems occupied a third zone (von Thünen 1966). It seems that, in Thünen's day, price conditions for lumber and fuelwood were more favorable near the city than they were for extensive cropping systems (Chisholm, 1962).

2.2.2 Forest Transition Theory

LSS effectively begins in the 1980s, with worldwide concerns about the rapid rates of forest destruction experienced in tropical countries. Rates of deforestation in the global south were then ~10 million ha per year, on average (Lanly 1982), with some national forests disappearing at rates as high as 3% per year (Allen and Barnes 1985). Most of the research at the time focused on explaining the causes for this massive forest decline, and it was well established that land clearing for agricultural production represented the main cause (Allen and Barnes 1985; Geist and Lambin 2002; Gibbs et al. 2010). That said, there was and continues to be a debate about the specific agents of deforestation, how land use systems articulate with political, economic and environmental contexts, and how feedbacks cross both scale and natural-human systems. In many respects, research on FT is an extension of earlier deforestation studies, in its focus on causative factors stemming from human behaviors.

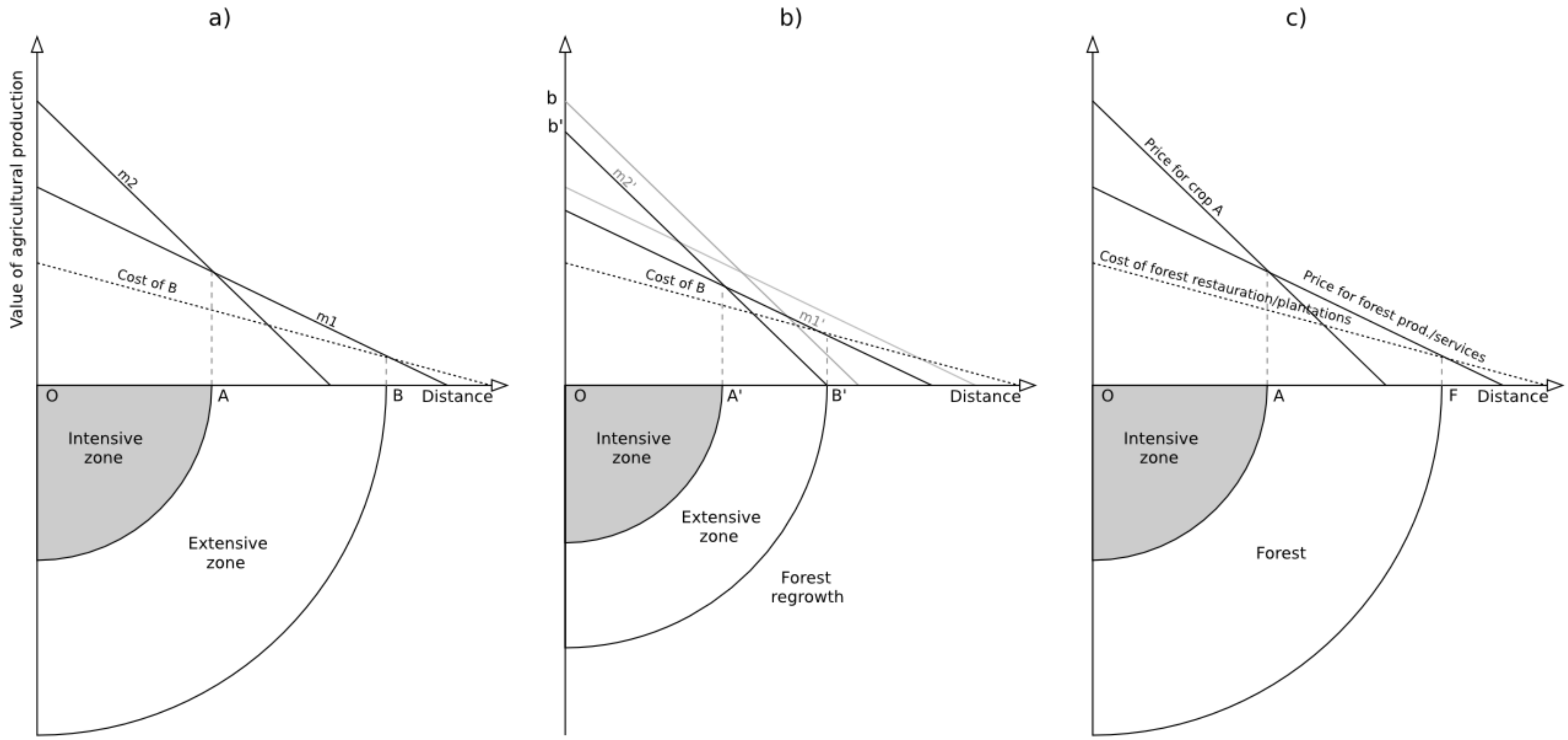

Figure 1. A Thünian interpretation of forest transitions.

The initial formulation of FT research posits a relationship between land cover dynamics and structural changes in a national economy. In schematic form, agricultural development drives deforestation, after which industrialization gives rise to a constellation of forces that counter forest encroachments. Thus, industrialization paves the way to an end of deforestation, with FT occurring as land is "spared" from agricultural production and the forest recovers lost ground (Mather 1992; Walker 1993; Grainger 1995b). Land sparing depends on three processes, namely agricultural intensification, rural out-migration, and changes in preferences that promote a societal demand for some degree of conservation (Walker 1993). Other FT pathways have been identified, and critiques are leveled at the sketch that has just been offered. For instance, the "forest scarcity" pathway emphasizes the role of forest resource shortages in boosting institutional responses to improve forestry management strategies and the expansion of plantations (Rudel et al. 2005).

Critics of early research on FT faulted its apparent congruence with developmentalist thinking and the assertion of necessary stages following in an isomorphic pattern (Perz 2007). For example, political ecologists question the alleged spontaneity of forest recovery in the face of industrial capitalism, arguing that FT often requires strong support from the state and the private sector in a struggle to restore the resource base destroyed during previous phases of growth but now required for the subsequent expansion of capitalism (Robbins and Fraser 2003). FT in Scotland resulted from this dialectical contradiction, one immersed in a global context that engendered an "industrial forest" for timber production and a native “natural” forest for the tourist industry. While Robbins and Fraser (2003) paint a different set of mechanisms as explanatory of FT, they do not reject the restorative potential of capitalism over the long-term. Others have pointed to the lack of attention to geographic (human and physical) and historical specificity in processes of FT, in particular for situations where FT has yet to occur despite the presence of the alleged preconditions (Perz 2007).

Mather (1992) introduced the term "forest areal transition" to refer to a shift from a period of net forest cover decline to a period of net forest cover expansion in long-term national land use dynamics of European and North American countries. In this early work, Mather showed that spatial forest recovery took place after a period of forest decline in developed countries and raised the question of whether developing nations undergoing high rates of deforestation would experience a similar outcome. In an attempt to understand such a shift in forest cover trends, he traced the historical processes driving FTs in Europe and North America. The most important determinants for him were trends in population growth and changing forest values (aesthetic and recreational) in urban societies. The combination of slow growth rates (or stable populations) and technical change could reduce demand for agricultural lands, although "the details and proximate causes may vary greatly from country to country ... just as the causes of deforestation are at least partly specific to localities" (Mather 1992, p. 372).

Walker (1993) independently discovered FT in research conducted in Puerto Rico, although he sought to generalize the concept by referring to it as "landscape turnaround," phenomena applicable to other ecosystems such as temperate grasslands and tropical savannas. Walker's approach focused on a two-stage transition in a national land use system, with FT following initial deforestation. This transition, in turn, tracked land use dynamics evolving "with structural changes in the national economy," including urbanization, the growth of manufacturing, development of labor and land saving agricultural technologies and changes in consumer preferences for recreational values. Walker was the first to document a widespread FT in Europe, North America, and the Pacific Rim for a large sample of countries (see Table 1). He also considered the FT in

Puerto Rico and speculated about its implications for deforestation in the global south, especially in countries such as Brazil.

Later on, Mather and Needle (1998) advanced a theoretical argument to FT. They argued that FTs in developed countries, or temperate FTs (after Rudel, Bates, and Machinguiashi 2002), can be explained by agricultural product gains resulting from adjusting agricultural production to better quality soils. In essence, they argue that in early phases of development, the location of farming is suboptimal because cropland has been selected at random, rendering agricultural productivity less than maximum. Population growth during this stage induces deforestation since increasing food production relies on the expansion of cropland. A later process of "getting to know" the land leads to selecting more fertile soils with greater productivity; this reduces the land area needed for food. Over time, agriculture is concentrated on the best soils, maximizing average productivity. At this point, if demand for food remains constant, it is possible to reduce cultivated area and free less productive areas to revert to forest.

With this basic model of agricultural adjustment Mather and Needle linked, in a causal mechanism, temperate forest transitions with specific historical patterns of economic development of industrialized nations, namely agricultural intensification and innovation, development of market economy and communication networks, and spatial concentration of population in urban centers. Note, however, that Walker (1993) initially laid out all of these factors explicitly. In any event, the overall process works as follows. Agricultural intensification and the development of new production technologies increase yields, thereby reducing the elasticity of agricultural land expansion in relation to population increments (thus, forest cover can remain constant or even increase with population growth). Markets and communication networks extend the scale of agricultural adjustments by connecting distant places, changing the competitive advantages of local production and allowing the flow of goods between productive and marginal locations. This process also implies the re-allocation of labor, even if such factor is not formally incorporated into the agricultural adjustment model. The release of land implies the release of labor from agriculture and therefore rural areas that were once forested. The emergence of cities and non-agricultural employment due to industrialization, where displaced agricultural labor relocates, is a final component in the Mather and Needle approach, as it was with Walker (1993).

Other researchers developed additional hypotheses linking economic development and trends in forest cover. Forest example, Grainger (1993, 1995b) articulated the concept of *forestry* transition, which he related to national land use transition as a distinct process following an initial period of expansion of agricultural land into forests. In this model, both transitions have independent dynamics and are regulated by different processes; they also vary across societies. Simply put, the forestry transition occurs when forest replenishment is more important than the national land use transition generative of agricultural land. Grainger made this distinction to incorporate potential delays in FT following long periods after deforestation has ended and to explain the underlying drivers of transition dynamics separately. For example, completely different factors drive active reforestation with forest cultivation and passive successional forest regrowth following agricultural abandonment.

Even though tropical deforestation continues, with rates reaching up to ~13 million ha per year (FAO 2010), the FT concept has attracted growing attention, and there is strong interest in explaining how it is that forest expansions represent the dominant dynamic in different parts of the world. Related research varies from worldwide cross-country comparisons to household-level analysis. Walker's (1993) study was already mentioned. Similarly, Rudel (1998) analyzes forest cover trends from 1922 to 1990, using cross-sectional data from OECD and non-OECD member countries. He finds that several countries reveal FT for the time period; these occur mainly in Europe and Asia. The FTs in question appear to manifest two primary pathways. One is economic development or normative transition (Grainger 1995b), observed in countries such as Japan and Puerto Rico. The other is a forest scarcity path observed in countries such as China, where substantial efforts to reforest previously exhausted woodlands have been undertaken by rural communities, with strong support from the State.

More recently and of high relevance to this dissertation, Grau and Aide (2008) list 18 articles published between 1996 and 2008 reporting FTs across Latin America. Most of these studies describe local FTs for relatively small areas. However, there are exceptions in which FTs occur over extents equivalent to a nation state. One of these is the case of Puerto Rico, a Commonwealth of the US, where annual rates of forest recovery from 1940 to 1990 ranged between 0.63% (Rudel, Perez-Lugo, and Zichal 2000) and 9% (Walker 1993). Whichever number is considered, the magnitude of forest recovery is astonishing. Another remarkable case is the FT in El Salvador, where 7% of high dense and 30% of low dense tree covers recovered since 1990 (Hecht and Saatchi 2007). The Brazilian Legal Amazon provides another relevant example. Although not a nation *per se*, the region covers a very large area of ~5 million km^2. Here, Perz and Skole (2003) report declining rates of deforestation, with an increasing expansion of secondary forest for the period 1986-1992. Net secondary forest gains represent only 1%, in the aggregate; however, in old settlement areas of the lower basin, the authors report increases as high as 25%. Forest expansion in Puerto Rico, El Salvador and Amazonia reflect histories of agricultural land abandonment, where rural out-migration, non-agricultural employment and country specific contingencies have managed to pull and push rural people out of agricultural production, although with significant depopulation in the countryside (Hecht and Saatchi 2007; Hecht 2010).

Other studies undertaken at more localized scales have emphasized changes in peasant livelihood strategies. For example, Rudel et al. (2002) analyze an FT in the Peruvian Amazon, using remote sensing analysis and household level interviews to investigate the relationship between land change and household characteristics. A similar approach is undertaken by Schmook and Radel (2008) for the southern Yucátan in Mexico. Results from these two studies confirm incipient FT but diverge in terms of the effect of some drivers. In the Yucatán Peninsula, out-migration and non-agricultural labor market opportunities appear to be driving a decline in deforestation. By contrast, out-migration does not appear to promote FT in the Peruvian Amazon. Klooster (2003) and López et al. (2006) provide probably the most convincing case of a regional FT in Mexico. Here, relocation of labor to off-farm activities, and to some extent, rural out-migration, induced widespread agricultural abandonment. The new economy depends on forest products, however, so forest covers continue to decline amid sparing of land from agriculture.

Another important aspect is that studies tend to ignore spatial context and the scale issue, which is critical to understanding FT (Walker 2010). The spatial context (e.g. accessibility and employment opportunities) determines the engagement of rural people in non-agricultural activities (de Janvry and Sadoulet 2001; Araujo, de Janvry, and Sadoulet 2002). The process of reallocating agricultural production to better land is central to the concept of FT. Thus, the incorporation of the spatial context in FT studies will help clarify scale issues, such as regional interactions that facilitate localized FTs despite aggregate deforestation (Walker 2010). With these considerations in mind, the chapter now discusses the FT process as it is occurring in Latin

America.

Table 1. Forest Areas for Selected Countries and Puerto Rico (in ha).

Puerto Rico[a]			*United Kingdom*	
1928	587,000		1914	1,342,186
1940s	53,400		1990s	2,178,000
1980	250,000			
Greece			*Italy*	
1923	1,800,000		1870	5,025,910
1990s	5,754,000		1914	4,554,656
			1990s	8,063,000
Switzerland			*France*	
1923	939,271		1870	5,025,910
1990s	1,124,000		1914	4,554,656
			1990s	15,075,000
Norway			*Sweden*	
1923	6,882,591		1923	27,038,750
1990s	8,701,000		1990s	27,842,000
Spain			*Portugal*	
1923	6,836,437		1923	1,621,486
1990s	10,811,000		1990s	2,976,000
Japan			*Canada*[d]	
1923	18,866,396		1923	245,344,129
1990s	25,280,000		1990s	436,400,000
United States[b]				
Original	373,279,352			
1923[c]	222,672,065			
1990s	226,526,721			

[a] Excludes coffee shade; [b] Excludes Alaska. Figures include closed and open forest. [c] Includes ~33 million ha. of 'degraded' lands. [d] Includes the Dominion of Newfoundland. Source: Reproduced from Walker (1993).

Research on FTs in tropical countries has become a topic of increased interest for land change scientists and ecologists, and empirical evidence has raised high expectations that tropical forests might preserve themselves automatically via FT. This research appears to suggest a widespread FT across countries, driven by macroeconomic forces (Aide and Grau 2004; Grau and Aide 2008). Latin America does show FT occurring in places with high rates of rural out-migration and the replacement of agriculture by off-farm employment in the secondary and tertiary sectors. Nevertheless, a closer look shows FTs to be incipient and highly localized. Table 2 expands on Grau and Aide (Grau and Aide 2008) and presents a list of 12 case studies of forest transitions in Latin America reviewed by these authors, also displayed in Figure 2. Table 2 presents increases in forest cover area in square kilometers, the original forest extent, and the period analyzed as well. Here, we can make the following observations. First, most studies involve relatively small areal extents; half of them below 5,000 km^2 and all except three below 100,000 km^2. In addition to reduced areal extent, the studies also focus on relatively short-term land use dynamics, which contradicts the notion that FT involves national land use dynamics sustained over long durations, an important problem because the aggregated dynamics and causal explanations change across scales (Walker 2010). In fact, as this Table reveals, only two FTs are occurring on a national scale. One is in Puerto Rico, not a nation, but a Commonwealth of the US, where manufacturing is heavily subsidized, and immigration to the US is unrestricted (Walker 1993). The second is El Salvador, where a bloody civil war displaced a large part of the rural population during the 1980s (Hecht and Saatchi 2007). In sum, the evidence from case studies on local FTs is not sufficient to support a claim that FT is occurring on a continental scale in Latin America.

Table 2. Selected Latin American forest transitions.

CS	State/Region	Net increase	Forest area T_1	Period	Publication
1	Jujuy, Argentina	n.r.	n.r.	1970-1990	Morales et al. (2005)
2	Tucuman, Argentina	14	400[§]	1972-2006	Grau et al. (2008)
3	Patagonia, Argentina	237	930[§]	1913-1985	Kitzberger & Veblen (1999)
4	Mata Atlântica, Brazil	38,747	103,773[£]	1990-2005	Walker (2010)
5	Pará, Brazil	524	1,860	1985-1991	Moran et al. (1996)
6	Santa Catarina, Brazil	227	1,177[¥]	1970-1996	Baptista (2008)
7	Mato Grosso, Brazil	-385	1,909	1986-1999	Jepson (2005)
8	Amapa, Brazil	206	88,200[¥]	1986-1992	Perz and Skole (2003)
9	Guabo Valley, Costa Rica	<4	44.5[†]	1973-1997	Kull et al. (2007)
10	Morona Santiago, Ecuador	n.r.	1,364[†]	1987-1997	Rudel et al. (2002)
11	Lempira, Honduras	5	491[¥]	1987-1996	Southworth and Tucker (2001)
12	El Salvador	4,800	21,041[¥]	1990-2000	Hecht and Saatchi (2007)
13	Yucatán Peninsula, Mexico	193	17,663[§]	1987-1997	Bray and Klepeis (2005)
14	Dominican Republic	2,550	5,100	1984-2002	Grau et al. (2008)
15	Michoacán, Mexico	352	1,425[¥]	1975-2000	López et al. (López et al. 2006)
16	Michoacán, Mexico	n.r.	50[†]	1942-1999	Klooster (2003)
17	Panama	1,546	52,528[¥]	1992-2000	Wright and Samaniego (2008)

All figures are in square km. Estimates based on [§]Image boundary, [¥]Political boundary, and [£]Biome. Forest estimates include old forest, secondary growth, and plantations. [†]Indicate study site area instead. n.r. = Not reported. After Grau and Aide (2008).

Table 2. (cont'd).

CS	State/Region	Net increase	Forest area T_1	Period	Publication
18	Puerto Rico	1,966	534[¥]	1940-1980	Walker (1993, 199)
19	Puerto Rico	1,508	1,153[¥]	1948-1990	Lugo (2002)
20	Upper Cañete Valley, Peru	n.r.	n.r.	n.r.	Wiegers et al. (1999)
21	Para, Brazil	390	1,994[§]	1985-1991	Mausel et al. (1993)
22	Tarija, Bolivia	n.r.	n.r.	1906-1992	Preston et al. (1997)

Figure 2. Latin American Forest Transitions. Case study numbers referred in Table 1. Circles are proportional to forest area at T_1. Biomes Map from Olson et al. (2001).

2.3 Commodity chain research

As others have argued, global food production provides an essential context for investigating LC processes (Myers 1981; Hecht 1985). The dissertation research builds on this insight by applying a commodity chain framework to comprehend the impacts of globalization on both deforestation and forest transition. Changes in forest characteristics that follow in the wake of neoliberal reform are instances of the neoliberalization of nature (Castree 2008, 2010). Such a conceptualization departs from the classical Thünian approach by focusing on corporate actors capable of responding rapidly to dynamics in the world economy.

The commodity chain is a linked set of activities and processes leading to the creation of consumer goods (e.g., maize, beef). The cascade of inputs involved may include capital investments, raw materials, transportation mechanisms, and labor. World systems theorists (Hopkins and Wallerstein 1977, 1986) introduced the commodity chain construct, but it became a subject matter in itself after Gereffi and Korzeniewicz (1994), often referred to as the "global commodity chain" or GCC paradigm. There is, however, a significant disjuncture between Hopkins and Wallerstein's conceptualization and that offered by Gereffi and others (Bair 2009). The former follows the Marxist tradition of critical analyses, while the later strips the concept from all notions of power and domination in capitalist relations and offers a firm decision-maker-centered mode of institutional analysis. Power relations are clearly important in understanding human organization. However, the work of Gereffi and others usefully differentiates between production- and consumption-oriented chains and offers a conceptual framework to characterize commodity chains.

According to Gereffi (1995), a commodity chain has four main features including (1) an input-output structure (i.e., products and services linked sequentially in value-adding activities); (2) a distinct geography with raw materials at "production" nodes and final demand at "consumption" nodes, plus intermediate processing and distribution stages along the way; (3) a governance structure that allocates financial, material and human resources, as well as economic surpluses, across the chain; and (4) an institutional context encompassing government, labor regimes, non-governmental organizations (NGOs), and other regulatory bodies. Later, Gereffi et al. (2005) developed a more sophisticated theory of network governance grounded in transaction cost economics. These authors attempted to explain inter-firm organization (governance structure) on the basis of intra-firm strategies to cope with transaction costs. Firm strategies have three main determinants: the complexity of transactions, codifiability of information, and capability of suppliers. Depending on the specific combination of these key drivers, five forms of governance can be derived: Market, Modular, Relational, Captive, and Hierarchy, which in turn lie along a gradient of control exercised by lead firms; from pure arm's-length market transactions (Market) to full control over the production process (Hierarchy). As in transaction cost economics (Williamson 1979), GCC theory aims to predict the reach of firm boundaries along the value chain and states that the degree of control will increase with rising coordination costs and risk (uncertainty). However, it acknowledges the existence of different forms of coordination and control, other than complete vertical integration, as mechanisms to deal with complex inter-firm relations.

The GCC approach has become influential, although applications often neglect the equity issues articulated by world systems theory. More recent theorizations of commodity chains integrate effects at the consumption node with the social and natural conditions at the production node to show how one affects the other (Leslie 2002; Palpacuer 2008). They also invoke spatial concepts, such as territoriality and place, and embed chain stages in different locales with unique historical, environmental, and sociopolitical contexts (Hartwick 1998).

Although the commodity chain has been used to identify local environmental impacts at production nodes, such as the use of pesticides and the clearance of coffee shade to allow mechanization of production (Talbot 2004, 2009), explicit applications to LC are uncommon (but see Garrett, Lambin, and Naylor 2013; Gibbs et al. 2015). The argument advanced is as follows. Since food processing moves in spatial displacements from the production node or agricultural "place," to the final consumer, a series of input-output relations manifest spatially, which is to say that a chain territorializes *en route* to consumers (cf. Biles et al. 2007). These relations evolve as institutional environment changes, and with it, chain governance structures.

To articulate commodity chains with land change, the concept of a “Land Change Regime” (LCR) is advanced, taking LC as a broad empirical category affecting all types of land cover in both urban and rural settings. The dissertation considers forest gains and losses (temperate and tropical) at the scale of the nation-state, taking Mexico as its primary focus. Terminologically, the social and economic forces responsible for LC, including both distal drivers and proximate causation, are referred as LCR, in which case the interest here resides in describing the structure and function of Mexico's LCR in pre- and post-neoliberal reform periods. A primary hypothesis of the dissertation is that LCRs possess important linkages to the agricultural production system, in this case involving M&B. Figure 3 depicts Mexico's LCR by combining the distal driver/proximate causation heuristic with commodity chain production (supply) and consumption (demand) nodes, as well as with feedback from consumption in the form of "teleconnections." The formulation of the proximate/underlying causation heuristic arose with early studies addressing deforestation

(Geist and Lambin 2002). In this view, proximate drivers are defined as those processes related to the direct action of land use agents. For example, land clearings to expand grasslands for cattle raising or for chili plantations, construction of transportation infrastructure that facilitates forest encroachment, among others. Underlying drivers, on the other hand, are thought of as "fundamental social processes," the backdrop context of incentives and constraints affecting land use agents (e.g., agricultural subsidies and loans, development policies, and others). This heuristic has been useful in conceptualizing different spheres of influence of LC drivers. However, there has been little effort to advance it at a conceptual/theoretical level.

The concept of the LCR links structural conditions and economic behavior with specific forms of LC; for the Mexican case, this involves the agents, activities, territories, and institutions engaged in the production, delivery, and consumption of agro-commodities. At the proximate level, the LCR focuses on the individuals who decide whether to clear or abandon a plot or even corporations directly involved in production through contractual arrangements. Upward in the chain, such decisions are embedded in a social matrix of government development programs, food processors, distributors, wholesalers and retailers, consumer choices, and so on. Tying this to the institutional environment and Mexico's recent history, the implication is that changes in M&B commodity chains stemming from neoliberal reform have altered Mexico's LCR. In this dissertation, the terms commodity chain, production network and complex, are used to provide various representations of the agricultural sector, with chains indicating material movements through input-output relationships, networks including cross chain linkages, and complexes embedding the full web of commodity relations within social, institutional, and geographic context (Galván-Miyoshi, Walker, and Warf 2015).

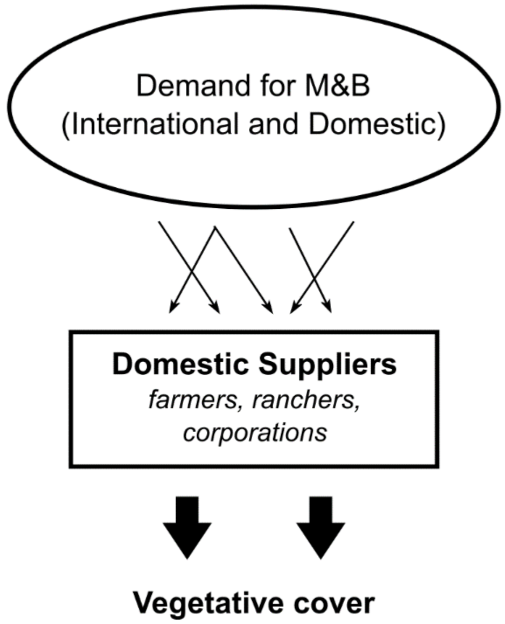

Figure 3. Conceptualization of Mexico's Land Change Regime.

2.4 Neoliberal reform and Mexican land change

Although globalization often refers to a multi-dimensional set of processes operating at international spheres, here is used to depict an ever-widening spatial domain for market activity. Globalization is not a driver or force in its own right, but a context through which LC drivers operate. Neoliberal reform comprises a set of policy interventions designed to consolidate a neoliberal "state;" these include deregulation, privatization, trade liberalization, and the facilitation of investment by foreign capital (Harvey 2007). Thus, neoliberalism involves both the reduction of trade barriers – a key aspect of economic globalization – and the privatization of state assets and communal lands, such as the *ejido*. Globalization and neoliberalism go hand in hand in the conceptual framework, with neoliberal reform paving the way for the globalization of Mexican markets while privatizing land in hopes of capturing new production efficiencies.

The impacts of globalization on LC have emerged as a major topic in LC science. Global forces are important drivers of both deforestation and forest transition in tropical ecosystems (Myers 1981; Aide and Grau 2004; Rudel et al. 2005; Hecht et al. 2006; Lambin and Meyfroidt 2010), and the literature is clear that LC agents adjust their decisions in direct response to neoliberal policy regimes and changing national economic structures. It is now well established that neoliberal reform (including GATT and NAFTA) represent path-breaking policy interventions with long-lasting consequences for land use systems. Several efforts conducted under the auspices of the Southern Yucatán Peninsula Region project (Turner, Geoghegan, and Foster 2004) make important contributions to the Mexican case at the household, local, and regional scales (Geoghegan et al. 2001; Klepeis and Vance 2003; Roy Chowdhury 2006, 2010; Roy Chowdhury and Turner II 2006; Radel and Schmook 2008; Busch and Vance 2011). At the mesoscale of the nation-state, efforts are fewer. An exception is Barbier and Burgess (1996), who analyzed cropland expansion before Mexico's entry into GATT and discussed the potential impacts of neoliberal reform on deforestation. These authors assessed the impact of NAFTA on deforestation[1] by examining the extent to which trade liberalization and changes in price-protection policies and subsidies affect the comparative returns of maize and cattle production. Elasticities for these two activities relative to output and input prices, credits, and population were estimated using a panel with data for 1970, 1980, and 1985. Output prices were the most important determinants of both maize and cattle comparative returns. For example, a 10% fall in maize prices could lead to a reduction of 3% in maize planted area. Similarly, a 10% fall in beef prices could lead to a reduction of 4% in cattle inventories. The outcome, however, would depend on the relative returns of cattle

[1]Due to the lack of land cover data at the time and they inferred a deforestation effect as proximate outcome of expansion of cropland area and cattle inventories.

ranching and maize planting, and both of these relative to returns to forest. Due to indirect effects, the final magnitude would also depend on the impact of liberalization on rural labor and wages, which could drive immigration into frontier areas, resulting in an increase in forest clearing. The authors suggest that the best scenario for Mexico's forest would be a combination of economic liberalization pushing farmers from subsistence agriculture and economic development pulling rural workers into off-farm employment. In this regard, research in Mexico has provided much useful insight into how structural reform at macro-scale in a nation state affects LC

Post-NAFTA LC studies, particularly those conducted under the auspices of the SYPR project, confirm the importance of neoliberal reform for Mexican LC, although the specific effects are far from uniform. Klepeis and Vance (2003) found that PROCAMPO (*Programa de Apoyos Directos al Campo*), a program of direct payments for agriculture deriving from NAFTA, created perverse incentives for land clearing and estimated that the program was responsible for 38% of the deforestation between 1986 and 1997 in the SYPR. On the other hand, this perverse effect seems to disappear once other institutional factors are taken into account (Roy Chowdhury and Turner II 2006). The impact of NAFTA on rural labor and wages has been high, with research suggesting that rural out-migration has outweighed immigration into forest frontiers, in particular to the US (at least until 2008, a turning point in US-Mexico migration patterns). In some cases, out-migration has driven agricultural abandonment and FTs (Klooster 2003; Bray and Klepeis 2005; López et al. 2006) or has slowed deforestation (Schmook and Radel 2008). In other cases, out-migration helps sustain agricultural activities (Radel, Schmook, and Méndez 2013) and boosts cattle ranching operations (García-Barrios et al. 2009; Radel, Schmook, and Chowdhury 2010; Busch and Vance 2011), a pattern consistent with the "Hollow Frontier" hypothesis. Diversification of agricultural activities towards rural non-farm employment seems to be another important trend in rural Mexico, but again with mixed effects on LC (Roy Chowdhury 2010). In general, LC research in Mexico has been rich in analysis of how socioeconomic, biophysical and geographic attributes determine land allocation at the household scale. Such work has been conducted for single regions, with a focus on peasant livelihoods (de Sherbinin et al. 2008). While such studies provide important insights, they are restricted to atomistic decision-makers operative in highly localized areas spanning only a few square kilometers; thus, they do not reveal how land use systems (in particular cattle ranching and maize farming) articulate and evolve with national or even regional agri-food networks. Some of the Mexican literature points in this direction (Tudela 1989; Villafuerte Solís, García, and Meza 1997), although it remains descriptive and regional in scope and, by now, is fairly outdated.

2.5 Limitations of prior research

Prior deforestation research considered policy effects of neoliberal reform, from some theoretical and methodological standpoints. More than any other body of research, FT literature frames the causative mechanisms of LC within a context of long-run structural changes in the conditions of agricultural production. Like the work on deforestation, theorization about FT has mostly converged on Thünian explanations (e.g. Barbier, Burgess, and Grainger 2009), confirming the relevance of the bid rent paradigm as a unifying framework for LC studies (Walker 2004). An interesting extension in this direction was developed by Walker (2010) to model regional interdependencies between FTs and deforestation.

The bid rent paradigm focuses exclusively on the allocation decisions of landowners and offers little insight into how other agents influence the spatial organization of land use systems. Also to be noted is that empirically focused research has favored detailed micro-social and high-resolution explanations at the expense of narrow spatial and temporal domains. Thus, it has often neglected global context and instead focused on internal characteristics such as population growth, economic structure, and ooothers. (Allen and Barnes 1985). It stands to reason that little is known about how globalization processes (e.g., market integration) affect inter-regional interactions within national land use systems, with implications for complex LC outcomes involving simultaneous deforestation and FT. This dissertation aims to explicate such complex outcomes at the national scale for Mexico, and it will do so by implementing the LCR concept to understand how neoliberal reform have shaped M&B commodity chains. To advance LSS, it is now necessary to account for decisions of heterogeneous agents and processes that condition land system dynamics far beyond the boundaries of the household or even the nation state. A shift of focus from proximate agents to network production structures may help shed some light in this direction.

3. THE MEXICAN CONTEXT

Mexico, an OECD country since 1994, is located in the northern hemisphere. It shares a border of 3,150 km (1950 miles) with the US and a border one-third this size with Guatemala and Belize (Figure 4). With almost 2 million square kilometers and 125 million inhabitants (in 2015), Mexico is the 13 largest country in the world in area and 11th in population size. With an average income per capita of $10,230 USD per year, it is classified as an upper-middle income country by the World Bank and is the second largest economy in Latin America after Brazil. Regional income disparities are large and average income ranges from $23,000 USD per capita per year in Mexico City to $3,600 in Chiapas. Still, a large proportion of the population, more than 55%, are poor, and more than 11% live in extreme poverty (CONEVAL 2014); indigenous communities rank among the poorest.

Mexico possesses one of the most complex and diverse mosaics of biomes in the world. Although it makes up only 1.4% of the world's continental land, we can find a sample of all major biomes, from desert and tundra to taiga and tropical perennial forest. Mexican vegetation is considered highly diverse, as rich as that found in the US and Canada combined. Mexico ranks 4th among the most biodiverse countries, hosting about 10% of all known biological species (Mittermeier and de Mittermeier 1992). Moreover, more than 40% are considered unique (endemic) to Mexico; the percentage is higher for some groups such as cacti (77%) and orchids (63%). Such a magnificent collection of life forms was made possible by the unique characteristics of Mexico's physical environment and biogeography: a complex array of landforms sitting near the Tropic of Cancer, the convergence of elements of neartic and neotropical ecozones during the Great American Interchange three million years ago, and other characteristics such as geological history and a highly diverse soil taxonomy.

Cultural and agronomic diversity match biological diversity. Between 69 and 291 linguistic groups evolved in the country, particularly, in its southern portion, which is part of Mesoamerica, one of the few cultural regions of the world where writing developed independently and where mathematics achieved the advanced concept of zero. Several high cultures flourished in ancient Mexico and left an important cultural legacy, still much alive today. Ancient civilizations inherited 15% of the crop varieties planted and consumed today around the world, among them maize, beans, tomato, cacao, tobacco, and avocado. Mexico remains an important center for the conservation and generation of agro-diversity. Hundreds of varieties of maize, beans, squash, and others, are still planted and selected by contemporary indigenous and smallholder communities (Brush 1995; Brush and Perales 2007).

Mexico also has a complex history. It was at the center of the European conquest of the Americas during the 16th century, which had dramatic consequences for the native populations. As with many other nations, the conquest of Mexico drained away many of its natural resources, after which powerful elites stymied processes of development and democratization. Industrialization took off late, only in the second half of the 20th century, and it relied on a huge expansion of agricultural lands and forest destruction. Deforestation, resource exploitation, contamination, and climate change currently impact Mexico. As a consequence, at least 127 species have become extinct, and 475 more are critically endangered (SEMARNAT 2013).

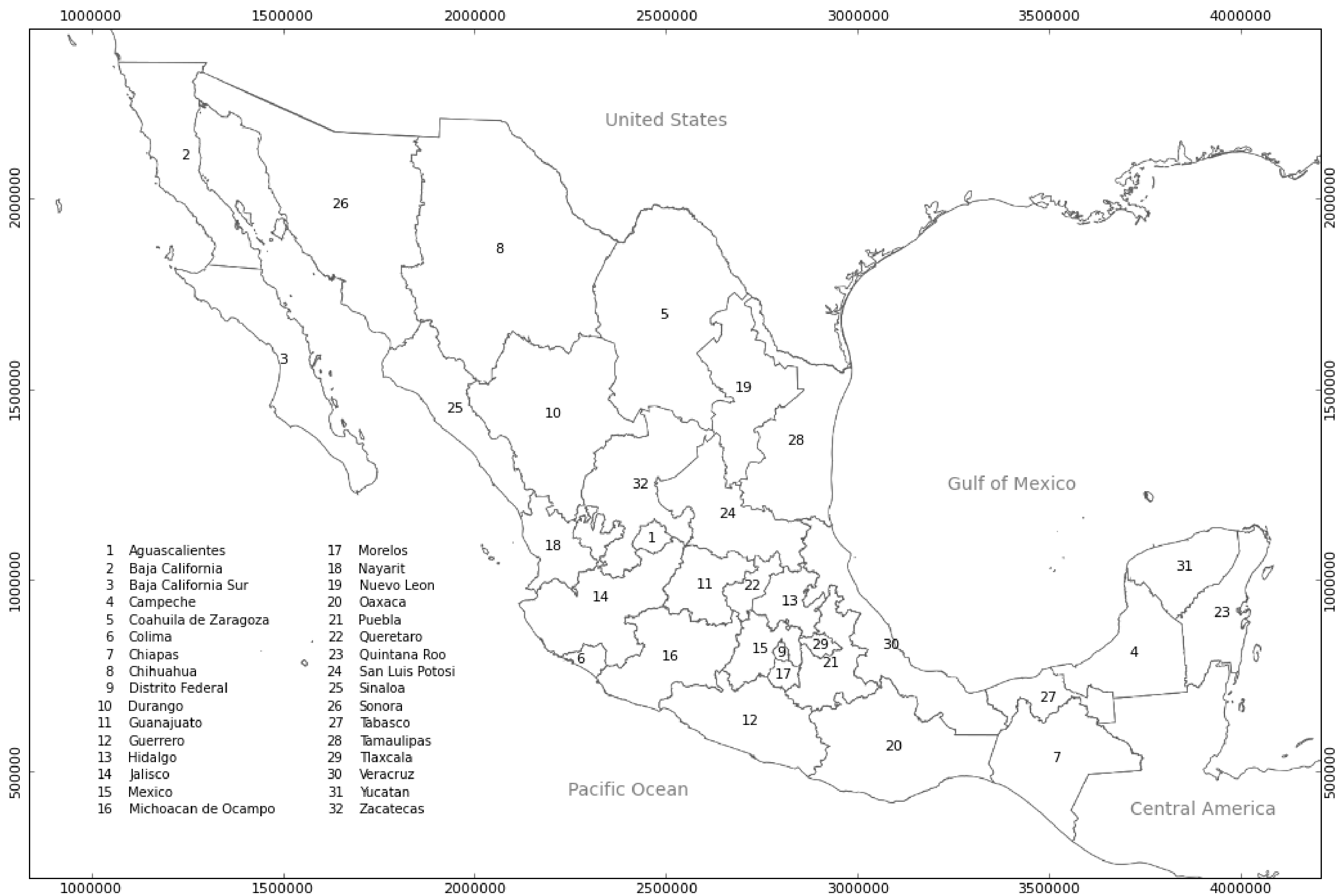

Figure 4. Political map of Mexico.

A walk through Mexico's history reveals how its land use has evolved and can shed light on connections between LCRs and specific development processes. To set the stage for this, the general characteristics of the country's physical environment are considered next.

3.1 Natural history

Eight large mountain ranges dissect the Mexican territory (Figure 5), creating a natural mosaic of unique niches along latitudinal and altitudinal gradients. Around parallel 20^{o}, the Neovolcanic Axis (NVA) rises in E-W direction, splitting the country into northern and southern divides. The NVA is arguably Mexico's most important geographic division; it imprints the cultural and socioeconomic traits of Mexican society, as well as its biogeography. The highest elevations are located within the NVA, including the five highest volcanoes in the country: Pico de Orizaba (5,636 m.a.s.l), Popocatepetl (5,500 m.a.s.l), Iztaccihuatl (5,230 m.a.s.l), Nevado de Toluca (4,680 m.a.s.l), and Malintzin (4,420 m.a.s.l). The NVA also marks the southern limit of three other important physiographic provinces located in the northern territories: the Sierra Madre Occidental (SMO), the Mexican Altiplano (MA), and the Sierra Madre Oriental (SOR). The most prominent and majestic is the SMO. It extends over 1,300 Km (~800 miles), from the Sonora-Arizona international border up to the NVA in northern Jalisco. It is 300 km at its widest point and 3000 m.a.s.l. at its highest. One of the hallmarks of the SMO is Copper Canyon, a UNESCO World Heritage Site, the largest canyon (or more precisely a system of canyons) in North America. The second largest mountain complex is the SOR. Located in the eastern portion of the country, it runs parallel to the SMO, from the Rio Grande on the international border (Coahuila-Texas) up to the NVA in northern Puebla. Its highest point reaches 3700 m.a.s.l. at Cerro San Rafael in Coahuila. The SMO and SOR flank the great Mexican Altiplano, an extensive area of relatively flat and arid to semi-arid highlands. The Sierra Nevada (US) extends south along the Peninsula of California and becomes the Sierra de California, the third largest mountain chain in northern Mexico. South of the NVA, yet another four mountain complexes rise on the horizon. The largest one is the Sierra Madre del Sur (SMS), arising near the coastal shores of Jalisco and Michoacán, and running southeast through Guerrero before fading into the plains of the Tehuantepec Isthmus in Oaxaca. In its southern reaches, the SMS joins the Sierra Norte de Oaxaca (SNO), a wide mountainous topography extending through northern Oaxaca and merging with the NVA in southern Puebla. The SNO is often designated as a province within the SMS. Two other isolated sierras imprint the landscape of the southern state of Chiapas, the Sierra Madre de Chiapas (also known as Altos de Chiapas) and the Cordillera Centro Americana. Both systems are part of the Central American landform and share a common geological origin.

Mexico's complex physiography is an important determinant of regional and local climatic patterns. Climate, landforms, and topographic relief interact to form a diverse mosaic of microenvironments. The Tropic of Cancer, located around parallel 23° 26' splits the country into an arid to semi-arid north with very hot summers and extreme temperature oscillations, and a humid to the sub-humid south, with summer monsoon rainfall and small oscillations between the minimum and maximum temperatures. The east coast of the Gulf of Mexico and the Yucatán Peninsula is heavily influenced by warm and humid air masses carried by the Gulf Stream, resulting in an E-W humidity gradient. The effect of the Pacific Trade Winds on the west coast is weaker due to the influence of cold and dry winds associated with the California Current System. However, as we move south, marine currents become warmer, exerting increasing influence on continental rainfall patterns. The difference in the effect of marine currents on coastal climate is influenced by the shape of the country, wide in the north and narrow in the south. More significant, the mountain ranges that flank the country along the western and eastern coasts represent effective barriers to ocean winds, resulting in rather abrupt changes in the precipitation received by inland territories.

Figure 6 shows three altitudinal profiles for transects crossing Mexico in the north near parallel 25° 47' (Figure 6a), the NVA near parallel 19° 10' (Figure 6b) and Chiapas and Tabasco using an N-S transect (Figure 6c) near Meridian 92° 45'. An additional y-axis is included showing cumulative annual precipitation. The most important nearby cities are also shown. Data for profiles were extracted from a Digital Elevation Model and a raster map with annual accumulated precipitation and a resolution of 1 square kilometer (see figure caption for data sources). The x-axis indicates distance in meters for 3-equal length transects. The figure depicts some physiographic characteristics of the continent we noted above. Mexico's territory narrows as we move from north to south; southern mountain ranges are also lower and smaller than northern landforms, and most of the inland territory comprises highlands flanked to the east and west (or the north and south in Chiapas) by mountain ranges with elevations above 2000 m.a.s.l. These physiographic traits have an important influence on rainfall patterns across Mexico, as can be seen in the precipitation curves of the figure: 1) Precipitation is high in the south and decreases as we move north beyond the Tropic of Cancer; 2) Precipitation drops sharply in the inland territory. 3) The east coast (the north in the case of Chiapas and Tabasco) is more humid than the west coast. The two largest North American deserts are located deep in the northern inland regions of Sonora and Chihuahua. The tropical wet forest is found along southern lands adjacent to the Gulf of Mexico.

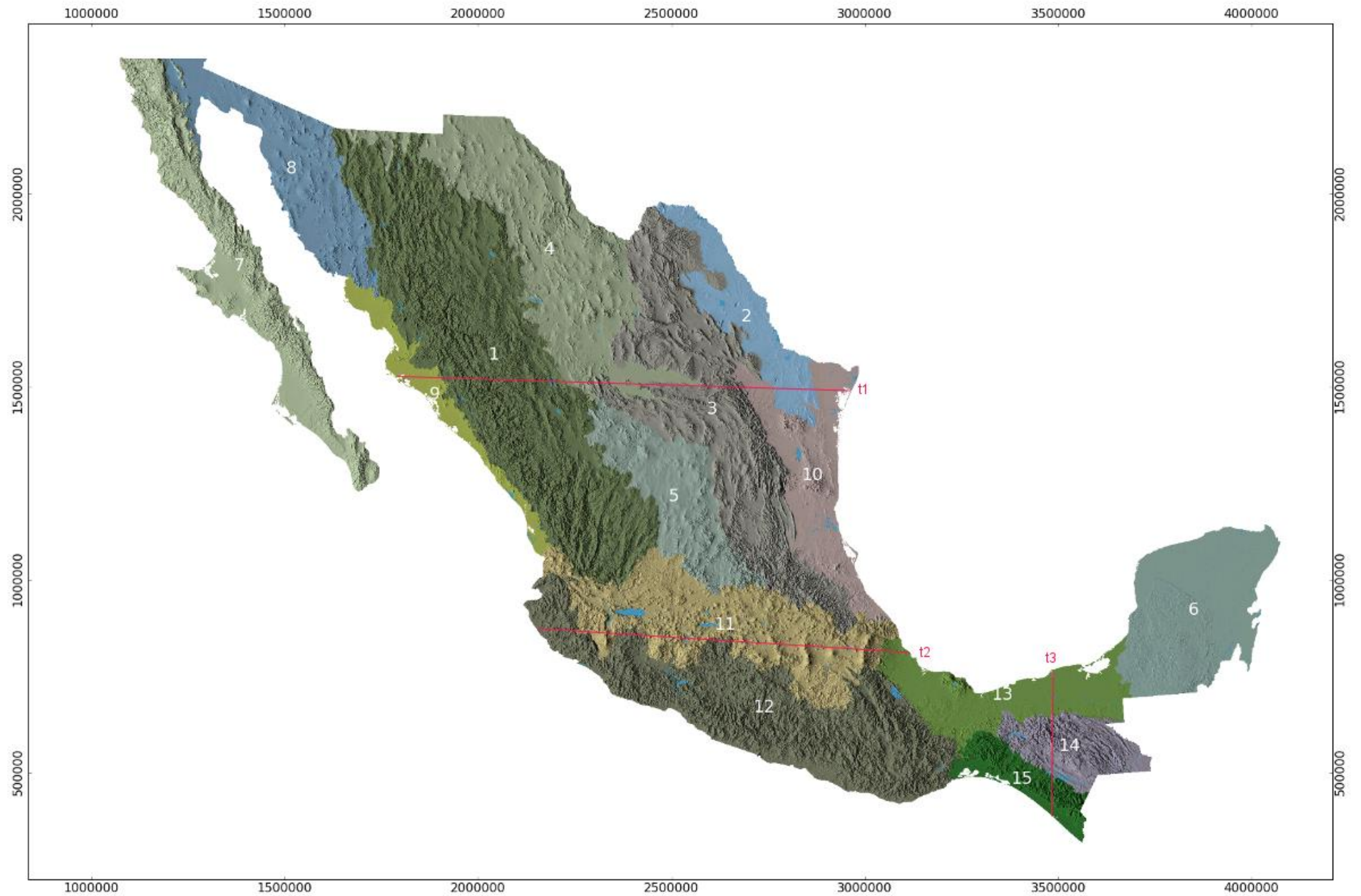

Figure 5. Physiographic Provinces of Mexico. 1) Sierra Madre Occidental, 2) Grandes Llanuras de Norteamérica, 3) Sierra Madre Oriental, 4) Sierras y Llanuras del Norte, 5) Mesa del Centro, 6) Península de Yucatán, 7) Península de Baja California, 8) Llanura Sonorense, 9) Llanura Costera del Pacifico, 10) Llanura Costera del Golfo Norte, 11) Eje Neovolcánico, 12) Sierra Madre del Sur, 13) Llanura Costera del Golfo Sur, 14) Sierras de Chiapas (Altos) y Guatemala, 15) Sierra Madre de Chiapas. Red lines (t1,t2,t3) indicate cross-sectional transects of Figure 6 below. Source: Carta Fisiográfica 1:1,000,000 (INEGI); Elevation data from Continuo de Elevaciones Mexicano 3.0 (INEGI 2015, available online at www.inegi.org.mx). Projection Lambert Conformal Conic (geographic coordinates in meters).

Topographic relief introduces important local variations to regional climatic patterns. For instance, terrain irregularities result in dry and warmer conditions on leeward slopes and humid and cooler conditions on windward ones. Most rainfall occurs on landforms at middle altitudes (between 1000 and 3000 m.a.s.l.) but flows downward across the drainage basins altering the water budget in the watershed system. Mountain systems create abundant water sources for valleys and coastal plains with semiarid conditions. The most important agricultural regions, such as the Pacific Coastal Plain of Sinaloa and Sonora, develop under these conditions.

Landforms are the most important factor influencing temperature gradients across the territory. Alexander von Humboldt in his description of the Kingdom of the New Spain noted how climate, and in general what he called the “physiognomy of the country,” was dependent upon altitude (Humboldt 1811). He described three major climatic zones based on altitude and temperature: *Tierra Caliente* (hot land) as lowlands with annual average temperatures between 24 - 30 ºC, *Tierra Templada* (temperate land) as mid-range elevation zones with annual average temperatures between 17 - 24 ºC, and *Tierra Fría* (cold land) for highlands with annual average temperatures below 10 ºC. This zonation is illustrative of the importance of altitude and climate patterns across Mexico. Using this classification, we observe that 26% of Mexico’s territory is *Tierra caliente*, 55% *Tierra templada*, and 19% *Tierra fría*. Indeed, Mexico is predominantly a subtropical country with mild temperatures.

While altitude is the most important determinant of regional climate patterns, it does not override the influence of latitude entirely, as Humboldt suggested. Figure 7 depicts the same altitudinal profiles shown in Figure 6, but this time showing in the right y-axis the annual mean and average minimum and maximum temperatures for the coldest and warmest months, respectively. We observe that temperature oscillations increase with latitude. For example, in Chihuahua the average range (the difference between minimum and maximum) of temperature is 33 ºC, for Tabasco it is 17 ºC.

The combination of complex landforms and climate patterns discussed previously is important for Mexico's biogeography and overall biological diversity for two reasons. First, it provides a rich suite of niches where biotic elements with distinct biogeographic origin can develop. Mexico's biomes share several elements with North America, Central America, and South America. Some similarities in species composition with the Caribbean Region, Asia, and Africa also exist (Rzedowski, 2006). Such affinities include species from a wide range of environments: from alpine to tropical elements and from desserts to perennial forests. Shared elements are found not only among continuous or proximate locations but also across very distant biotopes such as the grasslands at the highest elevations in Mexico and the Andes in South America. Strong similarities exist between southern Mexico and Central America, commonly held as a single region from a floristic standpoint. There are also important affinities, particularly of tree species, between the western US and northern Mexico. The northern portion of the Yucatán Peninsula and the Antilles share an important number of species, while similarities with Asian flora and humid mountainous environments are common. Affinities with Africa are more scarce and diffuse. Second, the complex topographic relief creates a wealth of relatively isolated microenvironments. This condition allowed important processes of biological speciation during the Pleistocene climatic fluctuations. As a result, Mexico is home to many unique species found nowhere else. Environmental heterogeneity is higher in arid and semi-arid regions, where we find the highest level of endemism. Also, although humid tropical areas are much more diverse in number of species (or α diversity), arid and semi-arid zones host a higher number of biological communities (i.e. higher β diversity).

We can distinguish seven broad biome categories (CONABIO 2008) ranging from forests to deserts. 1) Tropical perennial forest (TPF), both neotropical perennial and semi-perennial components in Mexico can be found almost exclusively along the Gulf coastal plains, from northern Veracruz to the Yucatán Peninsula, as well as on a small stretch of the Pacific coast in Chiapas. Originally, TPF covered some 18 million ha. Today, only 9 million ha remains and, of these, 6 million ha are in a successional stage. These ecosystems host the highest number of species per area. 2) Tropical deciduous forest (TDF) includes plant communities different from those of semi-arid regions. TDF can be found mainly along the lowlands of the Pacific coast, from Sonora to Chiapas. It is also found in the east along the Gulf coast, in southern Tamaulipas and northern Veracruz, as well as in the northwestern half of the Yucatán Peninsula (here, the young calcareous soils create dryer conditions than expected, given its location). Considering species diversity, these biomes are not as rich as TPF. They nevertheless host a large number of endemic elements (25% of the genera and 40% of the plants). 3) Mountain Cloud Forest (MCF) includes several neotropical plant communities that grow between 800 to 2200 m.a.s.l. along the humid mountain ranges of the Gulf of Mexico and on a few windward slopes impacted by ocean breezes. Its original extent was about 3 million ha; this has decreased to 1.8 million ha, half of it in secondary growth; 4) Temperate Forest (TF) covers coniferous species, hardwoods, and mixed communities characteristic of the sub-humid regions along the mountain ranges that cross the country. Originally, these biomes covered some 44 million ha. Today 33 million ha remain with one-third as secondary forest; 5) Xerophyte shrublands (XS), with an original cover of 70 million ha, is the most extensive biome in Mexico. It includes a wide variety of plant communities from arid to semi-arid regions of the Mexican Altiplano and the northern desert. XS species are mostly of neotropical origin and have a high degree of endemism (44% at the genus level, 60% at the species level). Fifty-three million ha remain as primary vegetation, with 5 million ha showing some degree of alteration; 6) Natural Grasslands (G) include *zacatonales*, *páramos* and *sabanas* (grasslands, moors, and savannas) found in the highlands over 4300 m.a.s.l., as well as in areas with poor soils. Its original extent reached 19 million ha; only 8 million remains; 7) Wetlands include littorals, mangroves, and aquatic and subaquatic plant communities in transitional zones. Originally, these systems covered some 1.88 million ha, about half of which have disappeared to human land uses.

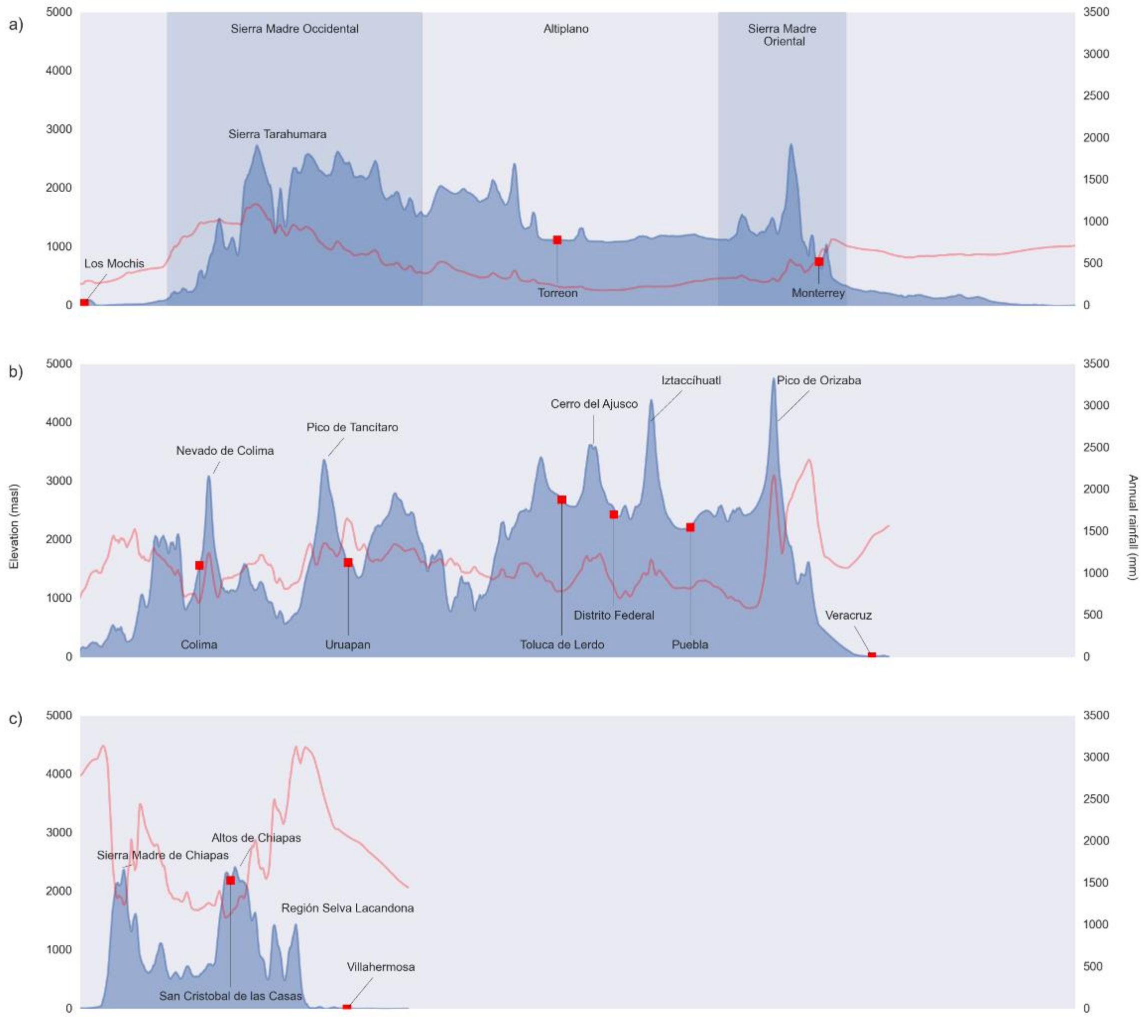

Figure 6. Altitudinal profiles and rainfall precipitation (right axis). Cross-sectional transects to produce this figure are shown in Figure 5: (a) E-W transect 1. (b) E-W transect 2. (c) S-N transect 3. Source: Elevation data from Continuo de Elevaciones Mexicano 3.0 (INEGI, available online: inegi.org.mx/geo/contenidos/datosrelieve); Rainfall data from the Atlas Climático Digital de México (UNAM, available online at atlasclimatico.unam.mx/atlas).

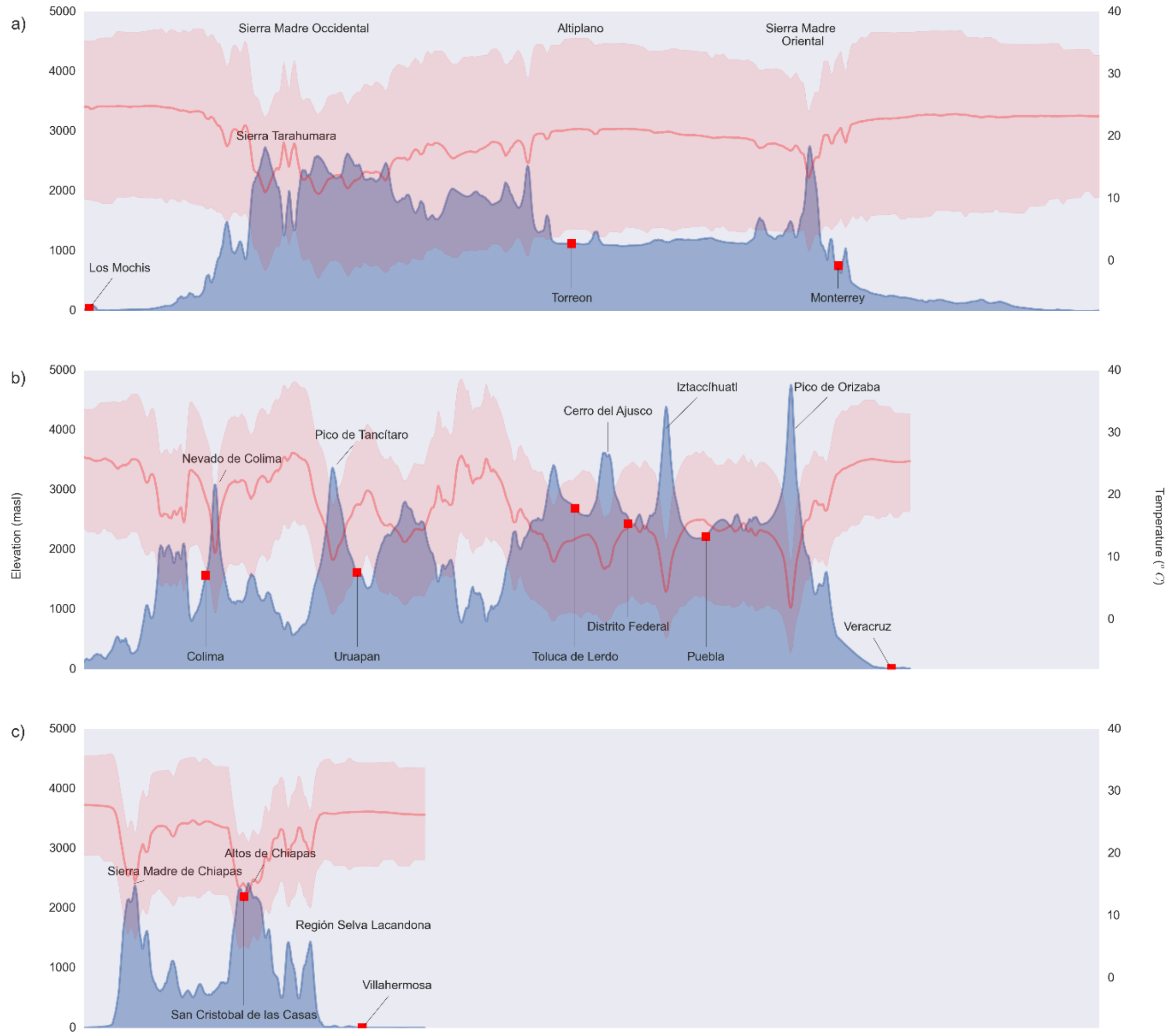

Figure 7. Altitudinal profiles and temperature oscillation (right axis). Cross-sectional transects to produce this figure are shown in Figure 5: (a) E-W transect 1. (b) E-W transect 2. (c) S-N transect 3. Curves are smoothed using a moving average. Source: Elevation data from the Continuo de Elevaciones Mexicano 3.0 (INEGI, available online: inegi.org.mx/geo/contenidos/datosrelieve); Average, minimum and maximum temperature data from Atlas Climático Digital de México (UNAM, available online at atlasclimatico.unam.mx/atlas).

3.2 Socio-historical context

3.2.1 Pre-Columbian times.

Several high cultures developed in what is today Mexico and Central America, in particular within the cultural denomination known as Mesoamerica. Mesoamerica includes the meridional portion of the Tropic of Cancer and extends to Guatemala and Belize and some portions along the Pacific Coast of Honduras, El Salvador, and Nicaragua. Pre-Columbian civilizations are descendants of Asian hunter-gatherer tribes that migrated across the Bering Strait during the Pleistocene glaciation when the frozen sea bridged Alaska and Siberia sometime between 13,000 - 33,000 years ago. However, it was not until 2000 B.C. that complex forms of social and political organization emerged. The consolidation of an agrarian society and, particularly, the domestication of maize (*Zea mays*), sometime between 4000 and 3000 B.C., was a necessary condition for the emergence of these cultures. This event also initiated a period of large-scale human-driven environmental transformations in Mexico and its neighboring areas.

Before the Spanish conquest, Mesoamerica was a populous region. Estimates put in 20 to 25 million people living in the region around 1519, on the eve of conquest (Evans and Webster 2001). Settlements and cities from a cluster of 11 cultures were flourishing in the region. Exchange of goods through well-developed markets was a very dynamic process, although tribute payment and dispossession by conquest were important mechanisms of interregional flows. A rich and diverse agriculture was the basis of pre-Columbian civilizations. Maize was the main food staple (as it is today), and its cultivation was a universal practice. Although only two small species were part of the livestock inventory (several dog races and turkey), pre-Columbian people domesticated a large variety of plants and had a profound botanical knowledge of wild varieties from their own and distant regions. Varieties domesticated in Mesoamerica include annual crops such as maize (Zea *mays*), beans (*Phaseolus vulgaris*), squash (*Cucurbita* spp.), pepper (*Capsicum spp.*), amaranth (*Amaranthus spp.*), and cotton (*Gossypium spp.*); and perennials such as henequen (*Agave spp.*), a variety of palm trees, avocado (*Persea americana*), and cocoa (*Theobroma cacao* and *T. bicolor*). The importance pre-Columbian cultures gave to plants is best illustrated in their botanical gardens. It was common for kings to have a designated place to cultivate and grow plants with medicinal, aromatic, and edible properties. Aztecs built aqueducts to deliver water from hundreds of kilometers away to gardens equipped with special baths (*Temazcales*) for resting and healing. Netzahualcoyotl, king of Texcoco, built one of the most important botanical gardens of his time, where he used to spend time writing poetry.

Pre-Columbian landscapes were modified in important ways, and archeological data suggest that Mesoamerican empires suffered from self-inflicted ecological catastrophes due to environmental degradation. Deforestation and land degradation combined with prolonged periods of drought caused the collapse of Toltec, Teotihuacán, and Mayan civilizations.

Slash-and-burn agriculture has been practiced in tropical and subtropical regions since 3000 B.C., and large tracts of tropical forest were subjected to early waves of deforestation and soil erosion (Evans and Webster 2001). Several techniques for intensifying agriculture were developed as well. Terracing was a widespread technique used to control soil erosion, preserve soil moisture, and level the ground of the steep terrain. Still today, it is possible to observe the imprinted landscapes of the Valley of Mexico, the Purhépecha plateau, and the Mayan Lowlands on the Yucatán Peninsula, among others. Some of these terraces are still in use, having witnessed more than 3000 uninterrupted agricultural cycles. Another technique was wetland agriculture, notoriously the *chinampas* of Tenochtitlan that fascinated the conquerors on their arrival to the central valleys. *Chinampas* are small artificial islands created with the muddy soil of the lake bottom and anchored by a perimeter of rapid-growth trees. By the arrival of the Spanish, the Aztecs had added a grid of several kilometers around the island on which the city of Tenochtitlán sat. The *chinampas* produced maize and other crops sold in the market, but they also served as land for further expansion of the city. Remnants of the Aztec wetland agricultural systems persist in the southern portion of Mexico City, across the old water channels of Xochimilco.

3.2.2 European conquest and colonialism

In 1519, Hernán Cortéz disembarked in Veracruz. It was the beginning of a journey that would lead to the demise of the dominant Mesoamerican civilization at the time and one of the worst human tragedies on record. The European conquest brought dramatic and permanent changes for the entire pre-Hispanic world, and thus, in the constellation of land change drivers. The most significant changes resulted from the "biological expansion" of Europe into the Americas, into what Alfred Crosby refers to as "Ecological Imperialism." Depopulation was rampant; land use systems with new animal and plant species were introduced; labor and land were articulated to a completely different social order; and a new biological bridge was put in place, this time connecting old and new world ecologies.

During the conquest and in the aftermath, disease, war, and massacres decimated the native population. Between 1519 and 1600 the Mesoamerican population declined 75-90 percent (Evans and Webster 2001). Smallpox, measles, influenza, tuberculosis, plague, and other diseases brought unintentionally by Spaniards, and their slaves took large numbers and were their reliable allies during their military campaigns, notoriously during the siege of Tenochtitlán, the Aztec capital, in

1521. Following the conquest, disease spread rapidly across the region and, in just a few decades, all over the continent, from the Great Lakes to the Patagonia. Disease devastated the production base of the native population, causing famines and a mutually reinforcing spiral that drove the pre-Hispanic world to the holocaust. Large tracts of agricultural land were released, but rather than forest transitions, agricultural abandonment resulted in increased land degradation. As the peasants fell to illness or fled to escape death, the cattle, pigs, sheep, goats, and chickens that accompanied the Spaniards took over the countryside and expanded unchecked in great numbers in a livestock Eden with abundant forage resources and few competitors and predators. However, the environment was fragile, and resources were limited. In a period of some sixty years, these animals, especially cattle and sheep, boomed over the region, exhausted the resource base and receded. The devastated landscape did not return to its original state. Instead, an ecological regime shift took place in which a shrub and mesquite semi-desert vegetation spread over the denuded soils and led to the hybrid landscape that we can observe today on the Mexican Altiplano. "A plague of sheep" was the term chosen by Melville (1997) in her account of the environmental collapse of the pre-Columbian landscape in the Mezquital Valley. Once a fertile valley for the Otomies, it became a dessert by the end of the 16th century.

The people that survived the conquest and disease were enslaved through the *Encomienda* system or fled to remote areas in the mountains, just to be found again, sooner or later, by one form of colonization or another. To organize labor, exact land rents, and ensure political control of the conquered territories, Hernán Cortéz established the *Encomienda* system.[2] This institution granted rights over a territory and its inhabitants to an individual (usually military servicing in the conquest

[2]The *encomienda* was an institution imported to Spain during the Roman invasions in the 19 B.C. and then to America by Cristobal Colón.

wars). The native population had to provide free labor and tributes to the *Encomendero* in exchange for protection and conversion to the Christian faith. In some respect, the *Encomienda* was similar to the Aztec tribute system. However, in practice, it was a form of instituted slavery. The harsh conditions of the *Encomienda* were another cause of population decline in the Americas. In the Antilles, for instance, *encomiendas* provoked the demise of the entire native populations, the reason Spaniards had to import African slaves. In 1540, largely because of the intervention of Bartolomeo de las Casas, the New Laws of the Indies prohibited subjecting indigenous people to mistreatment and forced labor. The creation of new grants was forbidden while existing *encomiendas* had to be transferred to the crown after the death of the *encomendero*. This system, known as *Repartimento*, aimed to end the *encomienda'*s monopoly of labor by changing forced labor into hired labor. However, the *encomienda* remained until the 18th century. As the Spanish world was consolidating in the new world, the Hacienda, the private property of the Spaniards, replaced the *Encomienda* and *Repartimento* systems.

During colonial rule, indigenous labor was reorganized around the Spanish economy, centered in gold and silver mining. As the new world economy expanded, native populations were forced to work in mines, agriculture, and emergent industries producing a variety of goods required by the new order. In this context, indigenous people developed a dual economy: they had to produce their own food, and thus subsistence agriculture remained, and they were forced to work for the Spaniards. This duality was inherited by subsequent generations of indigenous and mestizo peasants as they re-populated rural Mexico, and as the rulers changed from conquerors to a new-world-born elite with European ancestry. Although the *repartimento* required a wage for Indian labor, peasants never receive more than symbolic pay. Forced labor remained until the early 20th century, although not always enforced by physical means.

One of the most important land tenure systems in Mexico has its origins in the colonial period. During the *repartimento* and to facilitate control over the labor force and the evangelization process, indigenous peoples were brought to live in compact towns, known as *congregaciones*. Under the administration of the Church, *congregaciones* implemented the new territorial policy of the Spanish Crown aimed at creating a republic of Indians, where natives would be taught the Christian faith, produce for subsistence in the commons, and serve as a reserve of labor, and a Republic of Spaniards, ruled by private property, commercial production, and mining. Each c*ongregación* consisted of a church and a central plaza, from which parallel and perpendicular streets radiated. This urban structure remains a distinctive feature of Mexican towns. A territory held in common where peasants could cultivate and raise livestock, known as *ejido*, was granted as part of the *congregación*. By granting relative protection and a piece of land for production, *congregaciones* avoided the demise of the native population. They were also well suited to traditional indigenous forms of social organization and land use. While attempts to bring Indians into Spanish-ruled towns met strong opposition in most cases, in other cases *congregaciones* attained incredible harmony with indigenous communities. Vasco de Quiroga in Michoacán organized the congregations on the basis of specialization of labor and craftsmanship. Each town specialized in metallurgy, weaving, carpentry, cabinet-making, or pottery, and others. These early indigenous industrial towns were integrated to regional economies, providing a variety of goods to urban dwellers, the *hacienda*, and mining sectors. Four hundred years later, these towns are still producing the same goods, although their use value has changed. The system worked well while population density was low and land abundant.

As population increased and the economy of the New Spain boomed, Spaniards began to claim the territories held by indigenous communities and for that matter all properties of small peasants that were untitled. Mexico was entering a new moment of statehood formation, incipient industrialization, and expansion of private property. By the end of the colonial period, a hybrid Euro-American ecology emerged from the ashes of the conquest. Maize stood as the main icon of cultural identity and food security, as well as one of the most important legacies of the pre-Columbian civilizations. On the other hand, livestock in general and cattle, in particular, represented the cultural and ecological triumph over the pre-Columbian world. Maize was for Indians and peasants, cattle for Spaniards and its descendants. For the years to come, Mexico would struggle to find a balance in this hybridity. Large tracts of forest fell in the process.

3.2.3 Liberal creed and early industrialization

The colonial period officially came to an end with the declaration of independence in 1821. The period that followed was characterized by chaos and power struggles between the creole and mestizo ruling classes, between conservatives, trying to build an empire in the image of European powers and liberals pushing for a republic in the image of the United States, between the Church and the State, and finally between peasants and *terratenientes*. In the process, Mexico lost more than half of its former territory. In the north, after losing the Mexican-American war in 1848, Mexico ceded the territory that today form the states of Texas, New Mexico, Arizona, Nevada, Colorado, and California. Earlier, Central America, what is today Guatemala, El Salvador, Honduras, Nicaragua, and Costa Rica, withdrew by 1823. Overall, Mexico emerged as an independent country.

The consolidation of a liberal republic set the stage for economic growth and industrialization. Part of the government strategy to achieve modernization was the separation of the Church from the state and the expropriation of their assets. The privatization of the commons granted during the *repartimiento* was part of these plans. For the government, the riches and lands accumulated by the Church were "assets in dead hands." The government sought to transfer the vast extensions of lands accumulated by that institution over the course of the colonial period to private owners who wanted to unleash the productive potential of the country. For the government, the common lands of *repartimento* transferred to indigenous people by the Spanish Crown and the Church were part of those colonial institutions that prevented the country from modernizing. Those goals were implemented through the Lerdo Law (officially named *Ley para la Desamortización de Fincas Rústicas y Urbanas de las Corporaciones Civiles y Religiosas de México*). Under the Lerdo Law, indigenous communities were forced to split their lands among members of the community, or if the lands were leased they had to sell to the tenant at a price set by the government (Soberanes 2007). However, instead of creating a large class of private owners, these policies only helped to transfer huge amounts of land to *latifundios,* large *haciendas* owned by urban proprietors and foreign companies.

Dispossession of peasant communities took extreme proportions by the end of the 19th century. Under the rule of Porfirio Díaz, a handful of companies (*compañías deslindadoras*) were hired to survey and designate idle lands across the country in exchange for a share of the surveyed land. From 1883 to 1910, 59 million ha were surveyed and sold to large proprietors, foreign investors, and the railroad company. This situation set the stage for the Mexican Revolution, launched in 1910. The agrarian question was at the center of the demands of the Revolution. One of the main demands was the devolution of land ownership to the dispossessed indigenous communities, as well as the transfer of property rights of idle land to landless peasants.

By the end of the 19^{th} century, the Mexican Altiplano and neighboring regions were subjected to heavy transformation. By 1900, the iconic Aztec Lake of Texcoco was completely drained, and most of the landscape suffered the same fate as the Mezquital Valley. However, most of the territory, and in particular, the tropical regions remained wild. Economic activities in remote areas centered on mining, and extractive industries; gold and silver mining, logging and oil. There were large plantations, but they were limited to enclaves, such as henequen in the Yucatán Peninsula, and sugar and coffee in Morelos and Veracruz.

3.2.4 Agrarian reform and Industrialization

The state formation period that followed colonialism created a minimum set of conditions to initiate large-scale industrialization during the 20th century. However, it also inherited an unequal form of development that would have devastating consequences for the environment. The period of unprecedented economic expansion was also the most destructive in Mexico's land change regime history.

Large-scale industrialization and agrarian reform took off in the 1930s after President Lázaro Cárdenas (1934-1940) rose to power. The following 30 years, known as the "Mexican miracle," saw unprecedented rates of economic growth. Mexico transitioned from an essentially agrarian society into a largely urban-industrial one. Between 1940-1970 Mexico's GDP grew at an annual rate of growth above 6%, with manufacturing increasing at a rate of 8% per year. From 1950 to 1980, the urban population increased from 29% to 60%. This growth was heavily concentrated in a few cities, particularly Mexico City and Monterrey, the most important industrial centers at the time. For example, between 1940 and 1950 the population of Mexico City doubled, increasing from 1.6 to 2.9 million people. Urbanization was increasing rapidly across the US-Mexico border as well. As economic relations between the US and Mexico grew, the frontier cities of Tijuana, Mexicali and Ciudad Juárez became important nodes through which bilateral commerce took place (Garza 2002). Large cities also emerged with the expansion of agro-industrial enclaves, in particular, the northern cities of Hermosillo and Culiacán. In the Gulf states, the oil economy triggered the expansion of Coatzacoalcos-Minatitlán, Poza Rica, Ciudad del Carmen, and Villahermosa, among other enclaves, and indirectly, a boom in cattle raising. The rapid expansion of the economy during the economic miracle was largely engineered by a central government, which, by 1970, owned more than 400 state enterprises controlling oil, transport, manufacture, commerce, rural development, among others.

Before the 1980s, food policies were subordinated to a national strategy for import substitution, which prioritized the interests of the emerging urban-industrial complex. Like many developing economies in the post-WWII period, Mexico implemented a development strategy focused on the export of high value-added commodities (e.g., automobiles and electronics) (Lee and Cason 1994) and strong state intervention for the production of food at subsidized prices for the working classes. Control over food production and provision was considered strategic to achieving national sovereignty and security. Food commodity chains were territorialized within national borders and managed by a state-led governance structure (Gibbon 2001). The goal was to meet the demands of an impoverished peasant sector with little access to urban markets and to keep food inflation at bay in a context of high rates of population growth. By subsidizing food production through state-owned institutions (parastatals), the government contained political unrest even during times of economic turmoil and legitimation crises, while fortuitously ensuring a relatively peaceful transition to an outward development model (Ochoa 2001). During the import substitution industrialization period, the Mexican government built a huge complex of state-owned subsidiaries to control food commodity chains. Before neoliberal reform of the 1990s, the Mexican government heavily regulated food production and exercised a monopoly over functions such as land distribution, price and credit policies, extension services, and procurement systems.

After the Mexican Revolution, a constraint to unleashing the productive forces was the existence of a dislocated agricultural sector after years of dispossession and war, comprised of landless peasants and large *haciendas*. Uprisings demanding comprehensive agrarian reforms were a major source of conflict and political instability during the first half of the 20th century. Agrarian reform was the means by which the government achieved relative stability in the countryside and the integration of the peasantry into the national productive forces. A large peasant class developed in parallel as agrarian reform proceeded. From 1920 to 1992, the government transferred 51% of Mexican territory in the form of *ejidos* and *comunidades*. Land grants included 50% of the country's cropland area and 80% of the forest lands. Thus, while rural population decreased in relative terms and despite relentless rural out-migration, from 1950 to 1970 rural population grew in absolute numbers from 14 to 20 million people. In Mexico, industrialization was possible thanks to the enlargement of the agricultural population and the expansion of the agricultural frontier. A large reserve of labor ensured an abundant supply of urban and rural workers.

Agrarian reform was not much of a threat to forest biomes until the expansion of cattle grazing during the second half of the 20th century. The first large-scale wave of land grants distributed existing agricultural lands controlled by *haciendas*. Large agricultural projects developed in the fertile coastal plains of Sinaloa, Sonora, Baja California, Tamaulipas and Veracruz, and in regions such as the Apatzingán Valley in Michoacán and the Isthmus of Tehuantepec in Oaxaca. Large irrigation infrastructure was put in place to meet the requirements of these projects. In forest frontiers instead, President Lázaro Cárdenas created several *ejidos* focusing on forestry.

In central Mexico, he supported the exploitation of resin from pine. In the tropical lowlands of the Yucatán Peninsula, he established *ejidos* to extract the gum of the *Chicle* tree (*Manilkara zapota*). Deforestation was low at this point, and most forest biomes remained undisturbed.

The exhaustion of forestry and selective logging models led to an era of rapid expansion of grasslands for cattle ranching in the tropics. Between 1960 and 1970, more than 1 million ha were opened to grasslands in Veracruz, Chiapas, and Yucatán (Villafuerte Solís, García, and Meza 1997). In six southern states, grasslands increased by 150% between 1970 and 1988. By the end of the 20th century, about 80% of the Mexican territory, some 1.6 million km^2, was already under agricultural land uses, 20% on cropping and 60% on livestock production. Maize and cattle (for beef and dairy) were by far the most important agricultural commodities in terms of area. Maize planting represented about 40% of all cropland, while cattle took about 80% of all the land dedicated to animal husbandry. At this point, annual rates of deforestation of 2% or higher were common in southern Mexico (Bray and Klepeis 2005).

3.2.5 Neoliberal reform

The shift towards a neoliberal regime was inaugurated with Mexico's acceptance of GATT in 1986 and culminated with the signing of NAFTA in 1993 (although implementation occurred on January 1, 1994). Other reforms were implemented before and after this period, but the most significant changes took place between 1986 and 1994, a period referred to as the "second agrarian reform" (de Janvry et al. 1997). Reforms involved the abandonment of price controls, elimination of the parastatal system, and widespread privatization of the *ejidos* (de Janvry et al. 1997; Smith et al. 2009). The impact of neoliberal reform on food commodity chains was profound; food governance shifted from parastatals and small retailers to large domestic corporations and foreign multinationals, large scale, and capital-intensive production systems rapidly expanded, and dependence on global trade greatly increased.

However, far from a complete withdrawal of the state from food production, the government remains a key player, re-stating, negotiating, and legitimizing nationalistic goals around food production. In line with neoliberal principles, what is different now is a reliance on the paradigm of economic efficiency and market mechanisms, rather than distributional equity in matters of food. This change is particularly evident in federal programs and policies in support of maize production.

4. DATA AND RESEARCH DESIGN

Testing the hypotheses involves a two-step process. First, the dissertation needs to show that the changing territoriality of the M&B commodity chains is a response, at least in part, to neoliberal reform. The second question requires showing that these territorial changes underlie observed patterns of Mexican LC. Although a long-term policy process at work beginning in large part with GATT in 1986 is acknowledged, significant economic impacts do not occur until a few years later, given lag times in institutional change and implementation. For example, the parastatal system was not dismantled until the 1990s, with the privatization of storage, processing, and distribution facilities occurring as late as 1995 (Yúñez-Naude 2003). Similarly, important cuts in agricultural credit, subsidies to inputs, and elimination of guaranteed prices started between 1989 and 1991 (Gordillo de Anda et al. 1999; Villafuerte et al. 1997, Yúñez-Naude and Barceinas 2002). NAFTA, of course, is not implemented until 1994. Although some degree of market reform was underway toward the end of the 1980s, most policy interventions occur later, concentrating in the 1990s. Thus, the periodization for pre-reform (1980-1990) and post-reform LC (2002-2012) should bracket most of the significant impact.

4.1 Data sources

4.1.1 Primary data sources

The researcher completed 34 informal and 20 semi-structured interviews during a pre-dissertation research field trip and two fieldwork campaigns during July and August 2013 and

March and July of 2015. Table 3 and Table 4 list details for informal and semi-structured interviews, respectively (to comply with IRB rules, no names are included). Informal interviews include people I contacted to obtain specific pieces of information or people that provided data, references, or additional contacts. They include government officials, academics, and representatives from organizations, producers, and business employees within the maize or beef chains. Also, the researcher attended two industry conferences where I met with leading experts: the National Association of Retailers and Supermarkets (Spanish acronym ANTAD) and the International Conference on Meat, organized by the National Association of Feedlots (Spanish acronym AMEG). Data from a pre-dissertation research trip includes field observations and informal interviews conducted in southern Veracruz and eastern Chiapas, two of the most important regions for the production of weaned calves. Here, the researcher met with ranchers, local cattlemen associations, and brokers hired by feedlot companies.

Semi-structured interviews targeted high-level officials, business representatives (CEOs, managers or directors) and members from organizations (e.g. feedlot association). The institutions, organizations, and companies were selected *a priori,* considering their role in the commodity chain. Executives from the largest feedlot companies, representatives from the most important organizations of producers and retailers, e.g. AMEG, ANTAD, ANETIF, and government officers from federal agencies, such as the Secretary of Agriculture were chosen. The rationale to select the subjects was to target individuals with a national perspective in their specialty. For those firms or institutions not included in this selection, such as smaller feedlots and grain traders, subjects were chosen on a snowball basis. This turned out to be the most effective way to work because most people were only willing to meet with the researcher by recommendation from a trusted source. It was particularly important for people from the beef industry, who declared they had been subjected to kidnappings and extortion. The researcher developed a set of questions for each of four groups: retailers, business managers, government officials, and organizations (see Appendix for a sample of interview questions). Finally, the fieldwork involved trips to different locations, including Mexico City, Sinaloa, Jalisco, Querétaro, Michoacán, Veracruz, Chiapas, Mexico State, and Tabasco.

4.1.2 Secondary data sources

The second layer of information was extracted from governmental data repositories, archives, industry reports, published documents and gray literature. These sources were particularly useful to characterize pre-reform commodity chains. The abundant and rich literature on rural sociology from Mexican scholars who have been studying neoliberal reform in Mexico since the 1990s was an important asset.

Data on maize production, maize planted area, and cattle herds were obtained from two sources: (1) Agriculture yearbooks from the Mexican secretary of agriculture (Secretaría de Agricultura, Ganadería, Desarrollo Rural y Pesca -SAGARPA), with yearly data for Mexican states (1980-2014), Rural Development Districts (Distritos de Desarrollo Rural-DDR; 2003-2014), and *municipios* (2005-2014); and (2) Agricultural censuses from the Mexican Census Bureau (Instituto Nacional de Geografía y Estadística - INEGI) with data at state level every ten years (from 1930-1991, then 2007), and at *municipio* level for 1970, 1980, 1991, and 2007. These two data sources provide information on the same variables, but they sometimes disagree. All data was analyzed at *municipio* level. All data was geocoded using boundary shapefiles provided by INEGI. *Municipio* boundaries change from time to time due to the creation of new *municipios* or changes in their delimitation. *Municipios* showing important boundary changes–for example, new *municipios* created by splitting larger ones— were aggregated to ensure maximum similarity between inter-censal boundary definitions. As a result, Mexico's 2441 municipalities reduced to 2398.

Due to its clandestine nature, there are no official statistics regarding the exact number of animals entering Mexico from Central America. Although smuggled animals pass as Mexican cattle, they remain invisible to the agricultural census and other data collection efforts. Nevertheless, it is possible to gain insight into this trade by accessing freight registries from zoo-sanitary inspection points managed by state offices of SAGARPA. During fieldwork conducted in 2013 and 2015, the researcher collected data from the offices of the secretary of agriculture of Chiapas (Comité de Fomento y Protección Pecuaria del Estado de Chiapas) and of Veracruz (Comité de Fomento y Protección Pecuaria del Estado de Veracruz), and from a zoo-sanitary federal inspection point in Tabasco. These datasets provide information on animal trade for the most important trade route in southern Mexico. Statistics for Chiapas were available for 2003 and 2012, and data for Veracruz from 2008 to 2014. The zoo-sanitary inspection point data covered 2012 and 2013. These registries provide information on the number of animals traded per *municipio*, the purpose of the trade (e.g. breeding, slaughter, fattening), and the *municipio* of origin and destination. Information on the companies and individuals involved is also recorded but was not disclosed in the datasets provided. Most freight delivering feeder cattle to northern states travel across the state of Veracruz. Thus the dataset provided by this state's secretary of agriculture is the most complete. It includes a total of 205,000 entries with daily registries spanning seven years and more than 1000 *municipios* from the States of Veracruz, Chiapas, Oaxaca, Tabasco, Campeche, Quintana Roo, Yucatán, and others. After checking the consistency of the data and cleaning the registries, each entry was geocoded using a municipal boundary file from 2010. Only records for

Veracruz, Chiapas, Oaxaca, Tabasco, Campeche, Quintana Roo and Yucatán were analyzed.

LC statistics were estimated using land use/land cover maps published by INEGI. Land use and land cover maps are available in digital format (vector shapefiles) for 1980, 1993, 2002, and 2012. All maps are published at a 1:250,000 scale, although the spatial resolution of the images employed vary from 10 to 90 m. To minimize differences in map resolutions all maps were converted to raster format and resampled to 90 m. Statistics were then computed for all *municipios*. INEGI's land cover maps provide a detailed classification of land use and land cover types. The number of classes distinguished ranges between 150 and 300+. The dissertation, however, considers only tree-forest cover types, aggregated in three broad forest categories: temperate, tropical humid, and tropical dry forest. Using a strong definition of forest is clearly a conceptual limitation. LC affects all terrestrial biomes including deserts and prairies. LSS are aware of this, and they often opt for more inclusive terms (Walker 1993). However, adopting a more appropriate definition encounters the practical issue of data availability and quality. Because non-forested land cover types are difficult to classify and separate from human-induced land cover types there are no reliable data sets with full coverage for Mexico. Focusing only on tree-covers partially mitigates this problem.

Table 3. Informal Interviews.

Company/ Organization/ Office	**Role**	**Expertise**	**Date**	**Place**
SuKarne	Collection Center Manager	Feedlots	07/15/2013	San Andrés Tuxtla, Veracruz
Rancho Santa Rita	Manager	Feedlots	07/15/2013	San Andrés Tuxtla, Veracruz
CFPP	Operations coordinator	Cattle trade	07/29/2013	Tuxtla, Gutierrez
SAGARPA	Head of Department	Cattle trade	07/29/2013	Tuxtla, Gutierrez
SuKarne	Cattle rancher	Cattle trade	08/03/2013	Pico de Oro, Chiapas
Community	Cattle rancher	Cattle trade	08/03/2013	Marqués de Comillas, Chiapas
Local Cattlemen Association	President	Cattle trade	08/03/2013	Reforma Agraria, Chiapas
Community	Cattle rancher	Cattle trade	08/04/2013	Pico de Oro, Chiapas
Community	Cattle rancher	Cattle trade	08/04/2013	San Isidro, Chiapas
Community	Cattle rancher	Cattle trade	08/04/2013	Marqués de Comillas, Chiapas
Community	Collection Center Manager	Cattle trade	08/05/2013	Marqués de Comillas, Chiapas
Community	Cattle rancher	Cattle trade	08/05/2013	Marqués de Comillas, Chiapas
Community	Cattle rancher	Cattle trade	08/05/2013	Pico de Oro, Chiapas

Table 3. (cont'd)

Company/ Organization/ Office	**Role**	**Expertise**	**Date**	**Place**
SuKarne	Sales Manager	Beef markets	03/19/2015	Guadalajara, Jalisco
SuKarne	Manager Strategic Markets	Beef markets	03/19/2015	Guadalajara, Jalisco
Soriana	Sub-Director	Beef markets and marketing	03/19/2015	Guadalajara, Jalisco
Nielsen	Executive Director	Latino markets in the US	03/20/2015	Guadalajara, Jalisco
ANETIF	Technical Coordinator	Statistics on live-stock slaughter-houses	03/23/2015	Mexico City
ANETIF	Promotions Manager	Statistics on live-stock slaughter-houses	03/23/2015	Mexico City
COLPOS	Professor	Warehouses	03/24/2015	Texcoco, Estado de México
CEGA	Founder	Maize production	04/07/2015	Culiacán, Sinaloa
AMEG	Director	Feedlots	04/09/2015	Mexico City
Graduate Program on Animal Pro-duction, UACh	Professor	Quality and health regulations	04/10/2015	Texcoco, Estado de México
Graduate Program on Animal Pro-duction, UACh	Professor	Animal breeding	04/10/2015	Texcoco, Estado de México
Graduate Program on Animal Pro-duction, UACh	Dean	Animal feed	04/14/2015	Texcoco, Estado de México

Table 3. (cont'd)

Company/ Organization/ Office	**Role**	**Expertise**	**Date**	**Place**
B.M. Editors	Editor	Livestock production	04/16/2015	Mexico City
Slaughterhouse Los Arcos	Manager	Animal slaughter and processing	04/16/2015	Mexico City
AMPAS	Representative	Cattle production in Nuevo Leon	04/27/2015	Phone call
AMEG	Head of Department	Beef & feedlot statistics	04/28/2015	Mexico City
ALMER	Manager	Trade and grain storage	05/04/2015	Guadalajara, Jalisco
ASERCA	Head of Information Center	Grain trade and statistics, GIS	05/07/2015	Mexico City
ASERCA	Director	Grain storage	05/07/2015	Mexico City
ASERCA	Director	Grain trade, governmental programs	05/07/2015	Mexico City
SEDARPA	Supervisor of livestock farming	Cattle trade	07/26/2015	Jalapa, Veracruz

Table 4. Semi-structured interviews.

Key	Company/Office	Role	Area of expertise	Date	Place
I01	SAGARPA	Director	Livestock production, governmental programs	04/06/2015	Mexico City
I02	Grupo ANSA	General manager	Grain storage and trade	04/08/2015	Culiacán, Sinaloa
I03	Grupo AGROSILOS	Manager	Grain storage and trade	04/09/2015	Culiacán, Sinaloa
I04	Praderas Huastecas SV de PRL	General manager	Feedlots	04/16/2015	Mexico City
I05	SAGARPA	State Delegate	Livestock production, governmental programs	04/21/2015	Mexico City
I06	AMEG	Director	Feedlots	04/28/2015	Mexico City
I07	INAGRO	Operations manager	Grain trade	05/03/2015	Guadalajara, Jalisco
I08	Agro Operadora de Silos y Bodegas	Director	Grain conservation and certification	05/03/2015	Guadalajara, Jalisco
I09	ASERCA	Director	Governmental subsidies	07/06/2015	Mexico City
I10	GRAMOSA	Director	Grain conservation and certification	07/06/2015	Querétaro, Querétaro
I11	Frigorifico del Papaloapan	Director	Beef processing and packaging	07/09/2015	Veracruz, Veracruz

To comply with IRB regulations names and specific job positions were omitted from the table.

Table 4. (cont'd)

Key	Company/Office	Role	Area of expertise	Date	Place
I12	OCETIF	Director	Animal health and regulations	07/13/2015	Mexico City
I13	DIPCEN	Director	Beef markets	07/13/2015	Mexico City
I14	ALMER	Director	Grain trade	07/15/2015	Guadalajara, Jalisco
I15	Infomodity	Director	Market intelligence	07/15/2015	Guadalajara, Jalisco
I16	SICAMPO	Director	Grain trade	07/15/2015	Guadalajara, Jalisco
I17	Rancho las Margaritas	Director	Feedlots	07/16/2015	Veracruz
I18	Mexican Beef	Director	Promotion of beef exports	07/17/2015	Mexico City
I19	ANTAD	Director General de Relaciones con Gobierno	Supermarkets	07/22/2015	Mexico City
I20	AMPAS	Representative	Cattle production in Nuevo Leon	08/15/2015	Phone Interview

4.2 Reconstructing M&B commodity chains

Commodity chain analysis starts by reconstructing or characterizing the governance and input-output chain structures. The intent here is twofold. First, I analyze changes in chain governance and input-output structures between pre- and post-reforms periods. Second, I articulate institutional and organizational shifts to changes in national land use systems. The spatiality of chain transformations is considered here. To account for shifts in the territoriality of M&B commodity chains, the approach focuses on changes in extractive points of commodity origin, or source regions, given that proximate causation of LC has a basis in agricultural production. In other words, at this stage, I inquire how evolving governance strategies from institutions and firms led to the post-neoliberal form of territorial organization of national land use systems.

4.3 Spatial analysis and the production geography of M&B

Two motivations for using a spatial analysis framework are considered. One is methodological and concerns the structural properties of the regression model. Two main issues here are spatial autocorrelation, or spatial dependence, and spatial heterogeneity. Spatial autocorrelation is related to the idea that nearby things tend to be more similar than things located farther apart. Spatial autocorrelation is a "nuisance" in statistical modeling because the independence assumption of the linear regression model does not hold when present. Spatial autocorrelation is an important issue in the data employed. Soil conditions, weather patterns, ethnicity, and other attributes that span over contiguous territories highly influence agricultural patterns and land change variables. Spatial heterogeneity refers to the presence of spatial structure in the data (Anselin 1988), i.e. the existence of non-random spatial patterns in cross-sectional units. Such patterning may indicate the presence of group-wise heteroskedasticity or variable model coefficients (Anselin 1990, 2003) and may motivate the use of a regression specification with so-called spatial regimes (Anselin 1996; Anselin and Rey 2014).

The second motivation is empirical and is related to spatial heterogeneity as a source of information about the spatial pattern of agricultural change and the production geography of M&B. Specifically, the goal is to reveal clusters where herd sizes and maize cropland area increased or receded. The hypothesis is that regions showing large changes in agricultural variables are also the most affected by neoliberal reform. Here, distinctive spatial patterns may reflect the consolidation of a new commodity chain structure. For instance, clustering and spatial concentration are expected to increase as agriculture becomes industrialized; they are the underlying mechanisms of the so-called "development path" in forest transition theory (Rudel 2005). Prior research shows that spatial concentration of maize production increased after NAFTA (Sweeney et al. 2013), although no formal test has been conducted so far. Also, no attempt to analyze cold spots–regions where maize production receded—has been made.

Over the last few decades, geographers have developed a battery of methods to deal with spatial autocorrelation in econometric modeling (Anselin 1988; LeSage and Pace 2009) and, more traditionally, to analyze spatial structure (Getis and Ord 1992; Anselin 1995; Ord and Getis 1995). The approach developed by Anselin (1988, 1995) offers a consistent way to assess spatial autocorrelation and spatial heterogeneity, and is the one employed here. Anselin's framework is divided into two phases: exploratory spatial data analysis (ESDA) and spatial econometric modeling. The following paragraphs focus on ESDA and, section 4.4 presents the econometric approach.

The ESDA phase consists of assessing whether spatial autocorrelation and spatial heterogeneity are present in the data at all and, if so, proceed with their analysis. Moran's I, a measure of the covariance between a variable and its spatial lag (a mean value of the same variable observed within the neighborhood of each observation), is one of the most widely used methods to assess spatial autocorrelation. A straightforward interpretation of Moran's I is as a coefficient of a bivariate regression of the spatial lag on the variable itself (Anselin 1996); *I* can be expressed in compact form as:

$$I = \left(\frac{N}{S_0}\right) y'\, Wy/y'\, y$$

where N is the number of observations, $S_0 = \sum_i \sum_j w_{ij}$, w_{ij} is an element of the weight matrix *W* indicating whether a pair of observations are neighbors ($w_{ij} > 0$) or not ($w_{ij} = 0$), y is a vector of distances from the mean, and *Wy* is the spatial lag. When W is row standardized, $\sum_i w_{ij} = 1$, $S_0 =$ N and $I = y'Wy/y'y$.

As a global index of spatial association, Moran's I says nothing about how spatial dependence varies across space. However, it can be broken down into individual components using the Local Moran's I (I_i) (Anselin 1995). Local Moran's I produces a Local Indicator of Spatial Association (LISA) allowing assessment of the impact of individual observations on the global index. I_i is defined as

$$I_i = z_i \sum_j w_{ij} z_j,$$

where z_i and z_j are mean deviations for each observation $(x_i - \bar{x})$, and w_{ij} is an element of the spatial weight matrix (W) as before. I_i has the following characteristics:

$$I = \sum_i I_i$$

$I_i > 0$ indicates positive spatial association (neighbors surrounded by other neighbors with similar, low or high, values); $I_i < 0$ indicates negative spatial association (neighbors surrounded by neighbors with dissimilar values).

A scatter plot of a variable, and its spatial lag yields a graph similar to the one shown in Figure 8, called the Moran scatter-plot. In the graph, four regions are distinguished, each one corresponding to a pattern of spatial association. Regions 1 and 3 group observations with positive spatial association; in region 1 (HH) we find observations with locally similar high values and in region 2 (LL), observations with locally similar low values. Region 2 and 4 correspond to observations with negative spatial association, either positive values surrounded by negative values (HL) or vice-versa (LH). Whether a given spatial unit is spatially associated with neighboring locations needs to be tested against the hypothesis of spatial randomness ($E(I_i) = 0$). The colored dots in the scatter-plot show observations with statistically significant I_i's, which we may interpret in several ways. In particular, they may (Anselin 1996):

- Represent outliers or leverage points relative to *I;*
- Represent spatial heterogeneity (spatial regimes);

- Represent significant spatial clustering or repulsion.

Local Moran's I is employed here to assess changes in the production geography of M&B. This statistic is useful for two reasons. First, it permits identification of regions where agricultural change is more dynamic and determinate of the spatial pattern of agricultural change, i.e. whether changes occur clustered in enclaves or dispersed across the territory. Clearly, the underlying processes driving these two spatial patterns are very different. Second, LISA can be used to model spatial structure and test whether spatial heterogeneity results from heteroskedasticity or differences in the functional form of the regression equation.

Two processes of particular interest at this point are spatial relocation and spatial concentration of production. Relocation is defined here simply as a simultaneous change in two opposite directions in two (or more) locations; i.e. existence of locations where production/cropland/herds decrease and locations where they increase. In this analysis, relocation of M&B is assessed using three variables: maize cropland area, maize output, and cattle herds at *municipio* level. For each variable, $\Delta L = L_{t+1} - L_t$ is estimated, where L is a vector with the change variable (maize output, maize cropland area, or cattle herds) between two points in time, 1991 and 2007. These are the most recent years for which data are available at *municipio* level and digital format in the agricultural census (INEGI). Results are shown in choropleth maps of ΔL, a useful first step to visually inspect the presence of spatial structure, and LISA maps.

Two forms of concentration are considered in this analysis. One is an aspatial form related to the distribution of a variable across observations. For example, the distribution of income or the share of maize production per *municipio*. The other form is spatial concentration and refers, for example, to the proximity of highly productive *municipios*. A simple way to inspect the aspatial form of concentration and its changes over time is the well-known Lorenz curve, employed to study the cumulative distribution of income or wealth across a population. In this case, the Lorenz curve is used to map the cumulative distribution of production on the cumulative distribution of *municipios*. Since our interest is to locate areas of high and low contribution to overall productivity a map is employed instead a graph. To simplify the map, each *municipio* was classified in one of four groups: (1) *municipios* that collectively contribute up to 50% of national maize output (red); (2) *municipios* that contribute with an additional 25% (orange); (3) *municipios* that contributed 15% to the national output (white); and (4) those that contributed 10% (light gray). The degree of concentration of production within *municipios* can be quantified with the Gini coefficient (G), given by the following equation (Damgaard and Weiner 2000):

$$G = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} |x_i - x_j|}{2n^2 \mu}$$

where $| x_i - x_j |$ is the absolute difference between all possible *municipio* pairs (x_i, x_j), n is the population (in this case, *municipios*), and μ is the average productivity. G takes values from 0 to 1; G = 0 would indicate a situation where all *municipios* produce exactly the same proportion of maize; G=1 indicates a situation where a single *municipio* concentrates 100% of the national production.

The second form is spatial concentration. While G gives us an indication of the concentration of production within *municipios*, it says nothing about the spatial concentration of *municipios* with high or low productivity. A global univariate Moran's I is more useful for this.

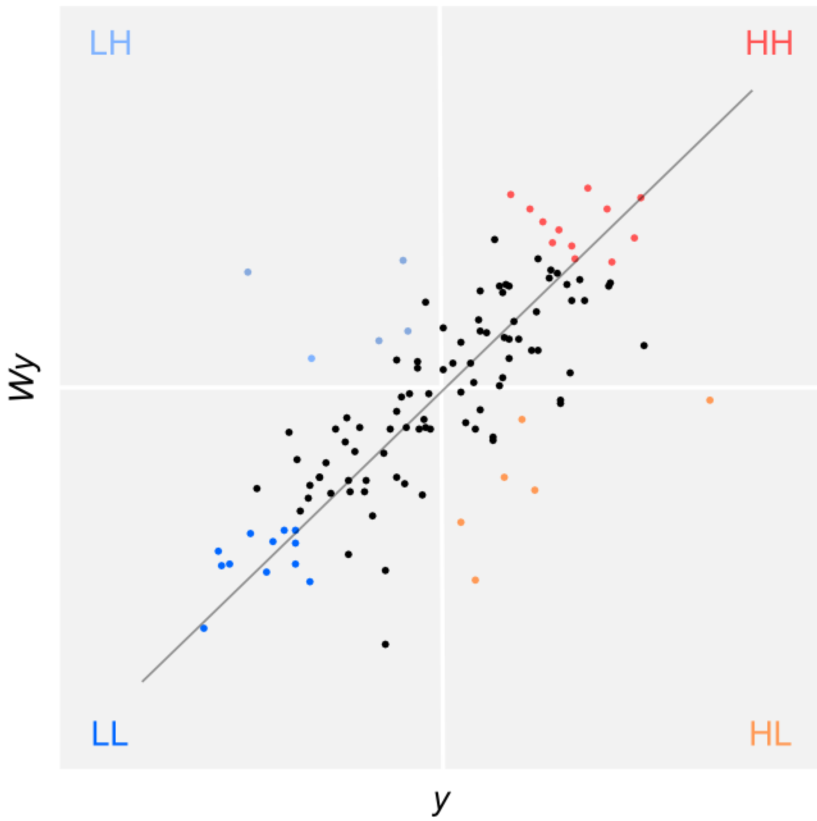

Figure 8. Moran scatter plot of the spatial lag (Wy) on y. The slope of the regression line is Moran's I. Quadrants LL and HH correspond to observations with positive local spatial association. Quadrants LH and HL correspond to observations with local negative spatial association. Colored dots indicate observations with significant spatial association.

4.4 Econometric approach

Originally, the dissertation proposed to assess pre- and post-reform effects using time series data for ΔL. Data availability at the *municipio* level proved difficult; however, a cross-sectional setting based on spatial regression with "regimes" was implemented instead (Anselin 1988). The term regime, as used in the acronym LCR, is in no way related to this econometric application. To avoid confusing the two terms, I will refer to spatial regime models as pooled SEMs. The analysis consisted of the following steps.

4.4.1 Modeling spatial structure and spatial dependence.

Detecting spatial structure using ESDA tools is a common approach in the literature. For instance, Dall'erba and Le Gallo (2008) apply hotspot analysis using the G-I* statistic (Ord and Getis 1995) to define clusters of rich and poor countries in the European Union. Resulting clusters were used to group regions with similar socioeconomic characteristics. The dissertation takes a slightly different approach by employing Local Moran I to assess spatial heterogeneity in ΔL and generate data partitions for the regression model. Two groups are thus distinguished: one with all municipios that fall within clusters or pockets of non-stationarity and one with all other observations. Although Anselin's local Moran's I allows assessment of positive and negative spatial autocorrelation, I consider only the former, which involves spatial clustering (quadrants HH and LL of Moran's scatter-plot). Rather than designating hot and cold spots as two distinct groups, as in Dall'erba and Le Gallo (2008), I combine HH and LL observations into a single group containing all clusters. This group consists of highly dynamic (large $|\Delta L|$) and contiguous *municipios,* and may consist of either regions highly affected by neoliberal reform or size-dependent outliers with heteroskedastic error terms. Because ΔL is given in raw figures and their magnitude is largely affected by the size of each *municipio,* being able to discern the source of spatial heterogeneity is a critical feature of the modeling approach.

As is well known, spatial dependency among variables undermines the utility of an aspatial regression model for inference. A modeling approach that explicitly accounts for spatial autocorrelation is indicated. Spatial dependency can be modeled in different ways in a regression structure. Following Anselin (1988), two fundamental specifications are the spatial lag and spatial error models. The spatial lag model or 'mixed regressive spatial autoregressive model' (SAR) introduces a spatial lag for the dependent variable. The population model considered in matrix notation is:

$$y = \lambda Wy + \beta X + \varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 I_n)$$

where β and σ are the parameters to be estimated, X is a matrix of covariates and ε is a vector of idiosyncratic errors. Additional elements include the spatial lag (Wy), with W specified beforehand, and the parameter λ indicating the strength of spatial dependence. Note that we take as our null hypothesis, H_0, for spatial autocorrelation that $\lambda = 0$, which means that the data are free of spatial dependence.

In the spatial error model (SEM), spatial dependence is introduced in the error term to account for uncertainty regarding the specification of parameters and variables (LeSage and Pace 2009). The SEM model is stated as

$$y = X\beta + u$$

$$u = \rho Wu + u$$

where ρ indicates the strength of spatial autocorrelation; here, we have as our null hypothesis, H_0, that $\rho = 0$ (no spatial dependency). A more complex specification of the SEM takes the form of an SAR with spatial dependence introduced among the covariates. This is called the Spatial Durbin Model (SDM),

$$y = \lambda W y + \beta X - \lambda W \beta X + \mu$$

$$\mu \sim N(0, \sigma_\mu^2 I_n)$$

Non-stationary spatial models are extensions of the regime models in time series analysis aimed to detect structural breaks in regression coefficients (e.g. Gregory and Hansen 1996). These models have been extended to spatial settings by Anselin (1988, 1990). In essence, a non-stationary spatial model enables testing to determine whether the coefficients of two or more regressions are different. If there are no statistical differences, then one model suffices to describe the process of interest. The simple case of a spatial lag non-stationary spatial model with two regimes in pooled form can be stated as

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \rho W \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} + \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix}$$

Note that in this equation the two regressions share the same spatial interaction term. It is also possible to allow the lag parameter to vary, in which case we would have two completely different spatial regression equations. The difference in regression coefficients can be assessed with the spatial Chow statistic (Chow 1960; Anselin 1990), an F test that assesses within group differences.

4.4.2 Implementation to the Mexican case.

The following model specifications were implemented. For the spatial lag model,

$$\Delta F_n = \rho W \Delta F_n + \Delta L_n \beta_{1,n} + C_n \beta_{2,n} + \varepsilon_n$$

where ΔF_n, the dependent variable, is a forest cover change vector. ΔL is the matrix of agricultural change variables as described before, and C is a matrix of control variables. *Municipio* area and change in population size variables populate this matrix. The subscript n indicates the data partition (or spatial regime), n = 2. The spatial error model takes the following form:

$$\Delta F_n = \Delta L_n \beta_{1,n} + C_n \beta_{2,n} + u_n$$

$$u_n = \rho W u_n + u_n$$

All variables are untransformed and are expressed in their original units. It is expected, for example, that changes in ΔL will induce proportional changes in ΔF; that is, one unit of land dedicated to agriculture will imply the loss of one unit of forest.

All spatial and regression analyses were implemented in PySAL (Rey and Anselin 2010), a python library for ESDA and spatial econometrics. The library offers a wide range of models and estimation methods, including non-stationary spatial model specifications and robust estimations for correcting heteroskedasticity. All coding was written and run in IPython (Perez and Granger 2007). For verification, some regression tests were implemented in the LeSage spatial econometric toolbox for MATLAB (LeSage and Pace 2009).

5. RESULTS AND DISCUSSION

This chapter consists of three parts. The first presents the evolution of Mexican M&B production networks following the implementation of neoliberal reform and identifies links between chain spatial reconfigurations and LC. The second section presents results of the spatial analysis of land use change. Finally, results of the econometric analysis are presented in the third section.

5.1 Evolution of M&B commodity chains

5.1.1 Falling prices, increasing maize production.

Maize is a highly politicized food in Mexico. Not only is maize the most important food staple, but it also bears multiple meanings as a symbol of class struggle, cultural heritage, national identity, and sovereignty. Given the preeminence of maize as a food source for a large portion of the population, in particular for the rural poor, for several decades the maize commodity chain was considered strategic and of key public interest. Such designation justified heavy state intervention and control of several nodes along the commodity chain. In fact, one of the most contentious issues of neoliberal reform was its effects on domestic maize production and trade. Serious concerns about the deleterious effects of trade liberalization on Mexico's food security and living conditions for smallholders, in particular for maize producers, were raised by critics of neoliberal reform (e.g. Barkin and Román 1982; Calva 1995). In fact, most analysts predicted falling domestic maize production. For example, Yúñez-Naude (1998) estimated that a 40% reduction in maize prices would result in a decline in maize output in smallholder communities ranging between 18% and 29%, depending on the productivity gains due to liberalization. Levy and van Wijnbergen (1994) estimated a displacement of 492,000 to 692,000 jobs and a 20% decline in output due to liberalization. Distinguishing between rainfed and irrigated lands, they concluded that producers with irrigation would benefit from NAFTA-based liberalization, with rents increasing between 2% and 25%. In one of the best-known assessments, de Janvry et al. (1995) inferred different effects for producers engaged in the market and subsistence producers. Relative isolation from the market and high transaction costs would immunize producers from the price shocks of liberalization. On the other hand, large capitalized producers could absorb the shock by shifting to other more profitable crops or by expanding production. The most vulnerable producers, then, would be those producers engaged in the market but with limited assets and little capital. This group comprised half of all maize producers and accounted for two-thirds of this grain output, thus implying a large effect on domestic maize production.

Contrary to all expectations, two decades after NAFTA, maize output nearly doubled above pre-reform levels, and maize cropland area increased slightly, despite 50% decline in prices when compared to pre-reform levels. Surprisingly, corn imports from the US rapidly increased in tandem with productivity gains, to the point that, by volume, corn is now the most important commodity traded between the US and Mexico (Zahniser et al. 2015). With an average of 10 million metric tons (MT) of corn imported every year since 2010, Mexico is now one of the largest grain markets for US producers, second only to Japan. Note that from this point on, I use the word *corn* to refer to the yellow maize variety –which represents 97% of all maize imports, and *maize* as a generic designation for all other varieties produced in Mexico. Why did maize production increase despite declining prices and increasing imports?

Research conducted at the household level suggests that, among *non-ejido* and *ejido* producers, maize production coupled with cattle raising emerged as widespread land use strategies to curb the effects of falling prices, subsidies, and credit in agriculture. Davis (2000) interviewed a sample of *ejido* households between 1990 and 1997 reporting a twofold increase in maize production. Producers with better assets (education, land, capital, etc.) were those with the largest increase. These advantages also translated into better access to government subsidies and private credit, as well as higher levels of rural non-farm income. On the other hand, small farms (< 5 ha) did not increase their cropland area, but they did not reduce it either. Eakin et al. (2014) refer to the former producers as the "agrarian winners" of neoliberal reform.

A common explanation advanced for this apparent paradox is that the shock effect of liberalization on grain markets was lower for maize than for other crops due to bias in the granting of subsidies (Davis 2000; Eakin, Bausch, and Sweeney 2014). The argument goes as follows. Given the importance of maize to food politics and security, the crop received more support from the State than others. Although the State released its control of the maize commodity chain (e.g. by shutting down State companies), other programs were put in place to buffer the effects of free trade policies and to facilitate the transition to an export-oriented agriculture. PROCAMPO, originally conceived as a cash transfer program for small producers to help them shift toward more valuable crops, was the main buffering instrument. Nevertheless, maize became by far the main crop subsidized. Because PROCAMPO was assigned on a per hectare basis, large farms were able to take larger shares of these transfers (Appendini 2013). *Alianza para el Campo*, another important initiative for agricultural development, sought to infuse capital into the agricultural sector. *Alianza,* which suffered several changes since implementation in 1995, provided capital liquidity for agricultural investments and had an important role in inducing intensification and commercial agriculture (Davis 2000; Roy Chowdhury 2006). Finally, the agency for support and services for marketing and market development (*Agencia de Servicios a la Comercialización y Desarrollo de Mercados Agropecuarios* -ASERCA), a branch of the Secretary of Agriculture created in 1991, implemented incentives for producers of market-oriented basic grains. Currently, ASERCA has implemented something similar to the corn subsidies of the US Farm Bill.[3] The agency operates mainly through three programs: forward contracting (*Programa de Agricultura por Contrato*), price insurance (*Coberturas de precios*), and minimum price support (*Ingreso Objetivo*). This program covers almost all maize farms with irrigated lands and one-fifth of the rain-dependent ones.[4] In 2014, a total of 14 million MT, nearly 60% of the national maize output was traded through ASERCA schemes (ASERCA 2014).

Summarizing, the argument advanced so far in the literature is that maize acted as a refuge crop in a context of declining agricultural prices, mainly because of governmental support to this crop. Government programs certainly buffered the effects of market liberalization and provided some incentives for maize producers, however, they do not fully explain why maize production not only persisted, but also expanded and thrived in some regions. In particular, the literature does not address the rapid expansion of the agro-industry. Indeed, producers were locked in maize production, but not necessarily as a result of biased governmental programs. In fact, only a few *Alianza* programs supported maize exclusively, while most incentives were conceived to support reconversion. Thus, in theory, producers could have chosen any other crop (as the government was expecting) and still receive the same subsidies. The bias in the granting of governmental

[3]However, the amount allocated to maize production is not even close to the subsidies contemplated in the Farm Bill.

[4]Based on data from an interview with the Director of the Office of Market Development (Desarrollo de Mercados de ASERCA), the office that administers the national program of forward contracting (July, 2015).

divestments seems the result of structural conditions of the Mexican economy, rather than a bias towards a crop or a rural class in particular. Using an assemblage of multivariate statistical tools, Biles and Pigozzi (2000), found that governmental credit and federal funding policies for rural development during the early reform period (1988-1994) were, indeed, biased towards the most urbanized states in northern and central Mexico. As these authors suggest, and Araujo and de Janvry (2004) later confirmed, there are important spillover effects between proximity to urban centers, agricultural dynamisms and manufacture and service employment (see also Biles 2003). Neoliberal reform changed the conditions for accumulation in agriculture, and the agro-industrial complex responded to a new set of incentives and constraints, triggering a whole set of transformations across the maize commodity chain. The government responded, with different degrees of success and acquiescence, to the demands of a highly heterogeneous sector, but did not shape the general conditions for agricultural development. The bias was not the cause or the pillar of a highly resilient maize sector, but the symptom of a particular socio-spatial structure. I argue, instead, that the livestock sector and the food industry were leading the transformations across M&B commodity chains in post-neoliberal Mexico. Understanding current land use transitions in Mexico, thus, requires looking into downward linkages across post-NAFTA food commodity chains, a theme scarcely addressed in the literature.

5.1.2 Maize and corn, imperfect substitutes.

Maize and corn are substitutes, but imperfect ones. Failure to assess the NAFTA effect on maize production was in part due to the implicit assumption that domestic production and US imports compete entirely in the same markets. Strictly speaking, corn and maize are two distinct commodities (see Figure 9), with corn being the most important feed grain and an intermediate product for the food processing industry (for production of starch, oil, xanthan gum, etc.). Maize, on the other hand, is the most important food staple in Mexico and a major component of traditional Mexican cuisine. More than half of the maize traded in Mexico goes to the tortilla industry, where it is processed as dry flour or as wet dough. A large proportion of the grain (25%) is consumed by rural households and never reaches the market.[5] In contrast, only a very small portion of corn is used to complement tortilla production or rural household consumption. Within the livestock sector, however, corn and maize compete to some extent, although corn is preferred for animal feed. The livestock sector is the primary consumer of corn and a top consumer of maize. In 2014, this sector required 65% of the annual corn supply and 12% of the annual maize supply.

Partial integration of corn and maize markets provides an additional explanation for the persistence of maize production for a simple reason: not all industries can substitute maize with corn. Thus, domestic maize production remains as important as it was 30 years ago. The fact that maize enters feed markets implies that its price is to some extent affected by corn prices; if maize prices are above corn prices, demand for maize-feed decreases, driving prices down. The opposite holds if corn prices are equal to or above maize prices. Except during the world crisis of 2007, maize prices have been falling since the second half of the 1980s, when the Mexican government embraced trade liberalization. Mexico is a major producer of maize and self-sufficient in this grain, but 71% of the demand for corn is still satisfied by imports. Since most imports are for animal feed, maize prices in Mexico are determined by corn prices issued by the Chicago Board of Trade (CBOT), and not the Kansas Board of Trade, which sets prices for maize in the US. Cointegration

[5] An important proportion of the grain retained for on-farm consumption is also used as feed for cattle and backyard livestock.

analysis, an econometric approach to assessing convergence between two or more commodity price series, confirms that corn and maize prices have fluctuated in tandem since the late 1980s,[6] with price transmission increasing after NAFTA (Villanueva, Naude, and Cote 2016). These studies also show that price convergence is only partial and, from time to time, prices of corn and maize diverge.

Driven by a boom in maize and meat production, integration of markets for corn and maize is increasing, resulting in even lower grain prices. Annual domestic maize output increased at an annual rate of 3.7% between 1990 and 2010, well above the annual rate of population growth (1.9% per year) and above the average GDP growth rate (2.9% per year). Meat production increased even faster, at an annual rate of 5.3%, during the same period. Productivity gains were nearly universal in Mexico, but the largest increases were observed (not surprisingly) in the most intensive nodes—those with more productive assets, irrigation, and higher input use. A response of the Mexican government in the light of increasing surplus maize production and expansion of the livestock sector was to push towards increased market integration of domestic grain with feed markets.

One of the goals pursued by ASERCA, through the program of forward contracting and price insurance, is to reduce transaction costs between maize producers and buyers from animal feed and milling industries.[7] ASERCA aims to make domestic maize competitive for large buyers,

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[6] Fiess and Lederman (2004) and McMillan et al. (2005) found that corn and maize prices moved together at least since the late 1980s and early 1990s. McMillan et al. found that the price differential between these two commodities was smaller after 1994, when controlling for variations caused by the 1995 devaluation crisis. Motamed et al. (2008) found no price transmission between US corn and Mexico maize prices, however their analysis focused on short term effects.

[7] Based on data from an interview with the Director of the Office of Market Development (Desarrollo de Mercados de ASERCA), the office that administers the national program of forward contracting and price insurance (July, 2015).

who otherwise might prefer to import corn from the US. The way this program works is as follows. The price of maize is fixed using the international price of corn published by the CBOT. Import, transport, and other transaction costs are added to the corn price on a regional basis to estimate the cost at point of sale (e.g. the cost of corn in Veracruz or in Mexico City). The cost of maize at point of sale is estimated in a similar way. ASERCA subsidizes the difference \$Corn - \$Maize if \$Maize > \$Corn. Also, 45% of the insurance price cost for buyers and 75% of the price insurance cost for maize (or corn) producers is covered when contracting through ASERCA. If the maize price falls below a threshold price, ASERCA can activate a minimum income subsidy to compensate producers. The ASERCA approach is considered a success by the government for a number of reasons. First, it links white maize production to animal feed markets, allocating excess domestic production into a rapidly growing sector in need of abundant and cheap grains. Second, by securing a price for producers and buyers it reduces the effects of speculators on domestic prices. Third, low maize prices benefit not only the livestock sector but also large milling corporations and grain trading companies.

The following section explores the linkages with the maize flour industry, a sector that greatly benefited during the neoliberal period. Linkages with the livestock sector and in particular with the beef commodity chain are further explored in section 5.1.2.

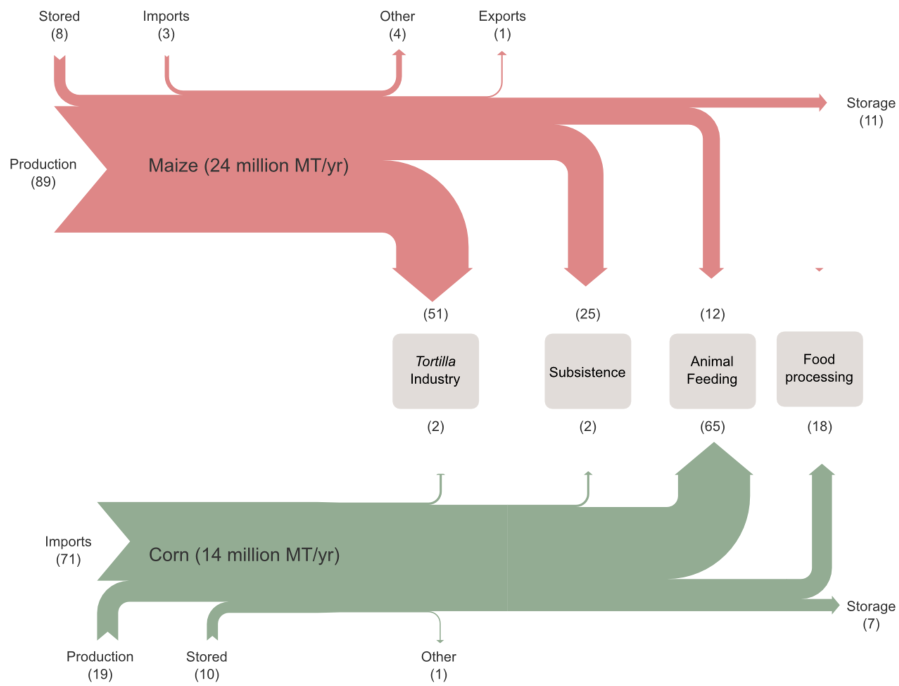

Figure 9. Maize and corn supply and demand. Source: Data from CIMA (Centro de Información de Mercados Agropecuarios). 2015. Panorama de maíz en México. Mexico City, Mexico: ASERCA-SAGARPA.

5.1.3 The rise of the maize flour industry.

Until 1993 one of the most heavily regulated sectors was the tortilla supply chain. The main regulating agency was the *Compañía Nacional de Subsistencias Populares* (CONASUPO), a state company that by 1975 administered a total of 16 subsidiaries and regulated not only all grains and dairy production but also a wide variety of consumer goods ranging from school supplies to construction materials (Grindle 1977). Regulation of the maize commodity chain involved six main subsidiaries operating at different nodes and in parallel to the private sector—with market shares varying by node and product, involving warehousing, distribution, retailing, and food processing (Figure 10a). At production nodes, the State was involved in grain storage through BURUCONSA for the *ejido* sector and ANSA for the private sector. DICONSA delivered subsidized grain (or maize dough) for tortilla manufacturing and maize-flour at retail points. In 1982 DICONSA administered more than 11,000 retail stores across urban and rural areas (Ochoa 2001). Within the food processing industry, State intervention focused on tortilla manufacturing through MICONSA and ICONSA, with a combined share of the flour market of 30% to 40% (Ochoa 2001).

As part of the austerity measures mandated by the International Monetary Fund, the federal government dismantled the parastatal system and transferred its functions and assets to the private sector. CONASUPO was shut down by executive order of President Ernesto Zedillo in 1999 (Yúñez–Naude 2003). Only one of its subsidiaries, DICONSA, remains today. Several other measures affected land distribution (privatization of the *ejido*), credit and finance, outreach services, rural development policies, etc. The pre-reform governance structure was replaced with what Gereffi (1995) calls 'buyer-driven commodity chains,' in which three nodes emerged as lead players: the maize flour industry, large brokers and distributors, and feed processors and animal fattening operations (Figure 10b). In the post-reform maize commodity chain, these large buyers effectively control maize prices, storage and distribution, and increasingly quality and safety standards. Grupo MASECA (GRUMA), the largest maize milling company in the world, and MINSA together control 96% of the domestic maize flour market (CIMA 2015). The multinational corporation Cargill is today a leading player in wholesale and retail and is increasing its participation in milling. DICONSA remains a big buyer, but today only distributes grain in small rural communities under the auspices of welfare programs. The livestock sector became the main grain consumer in this period, in particular, poultry farms, feedlots, and swine farms. Most maize imports are used for animal fattening and feed processing, two activities that have expanded at astonishing rates in Mexico since the liberalization of grain markets.

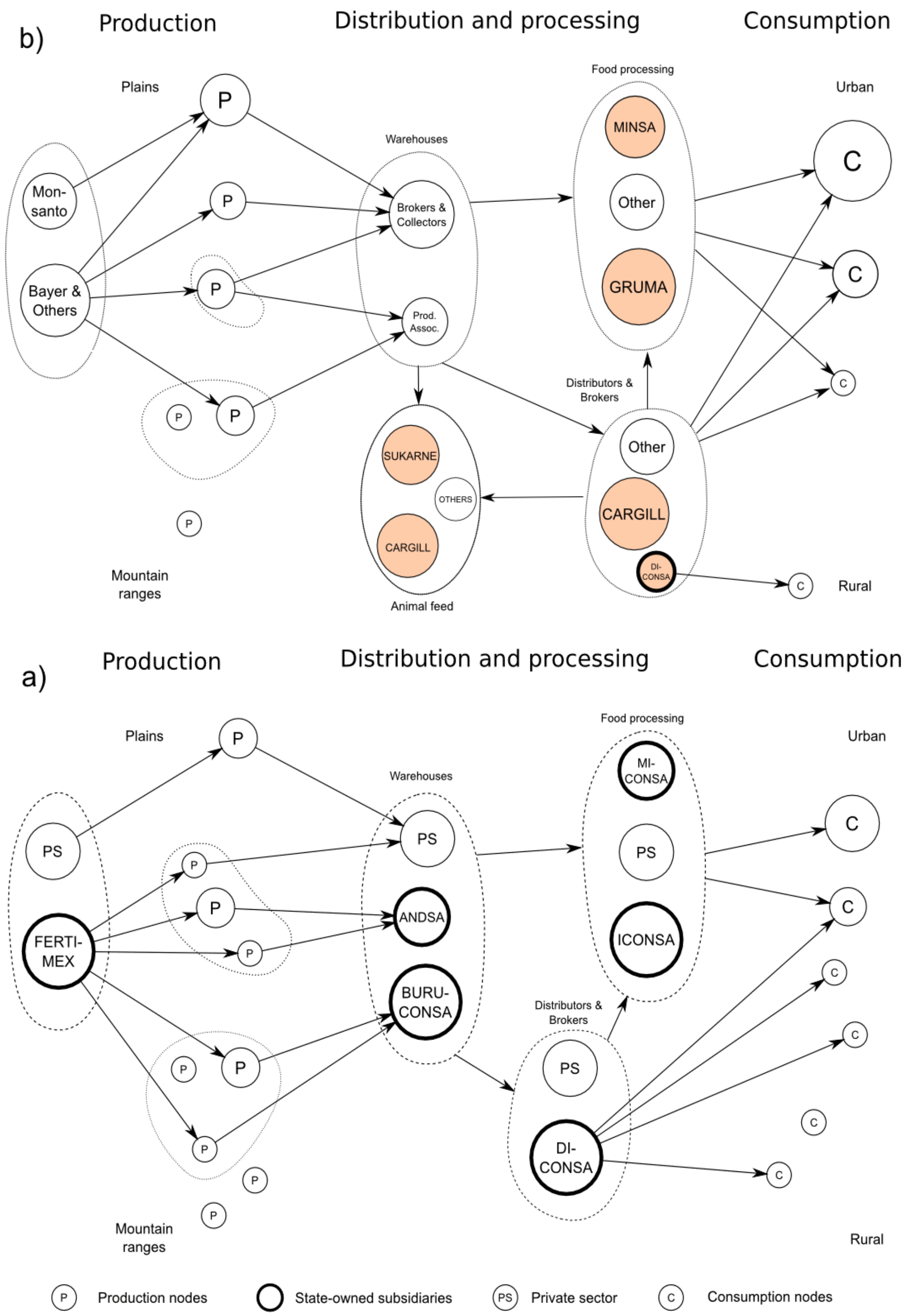

Figure 10. Maize input-output production network structure. (a) Pre-reforms production network. ICONSA (Industrias CONASUPO S.A.), MICONSA (Maíz Industrializado S.A.), DICONSA (Distribuidora CONASUPO S.A.), ANDSA (Almacenes Nacionales de Depósito S.A.), BURUCONSA (Bodegas Rurales CONASUPO S.A.), FERTIMEX (Guanos y Fertilizantes de México S.A.). (b) Post-reforms production network.

The 1990s was a period of rapid expansion and consolidation for the maize flour industry. During these years, the two leading companies, GRUMA and MINSA, enjoyed a propitious environment for growth. This phase also benefited GRUMA, whose owner and top rank executives had close ties to the administration of Salinas de Gortari (1988-1994).[8] This was a key advantage in a moment when inflows of foreign capital and flexible loans were rapidly increasing as a result of finance liberalization, and when restrictions and governmental controls on the maize commodity chain were being lifted. Trade liberalization was proceeding apace, and maize prices were falling.

The road to full liberalization did not begin with NAFTA. Four years before the treaty came into effect, the government of Salinas began an aggressive process of de-regulation of financial markets. Although initial steps were taken in 1988, the most important reforms took place between 1989 and 1993 and were greatly influenced by the US and Canada during NAFTA negotiations (initiated in 1990). These reforms included the privatization of banks[9] and changes to the Security Markets Law to allow Mexican firms to invest in foreign stock markets, and foreign investors to invest in Mexican money and stock markets. Interest rate ceilings were also eliminated (Vos, Taylor, and Barros 2002). Results were quick to show. The reforms, in combinations with the emergence of the largest trading block of the period and low-interest rates in the US, boosted a massive inflow of capital (Bolling, Neff, and Handy 1998; Kwon 2012). Between 1985 and 1995, US FDI quadrupled (Bolling, Neff, and Handy 1998), while gross capital inflows increased by an

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[8] Roberto González Moreno, founder of GRUMA was friend to Raúl Salinas de Gortari (president Salinas' brother), then a high executive of CONASUPO (Ochoa 2013), and to Carlos Hank González, Secretary of Agriculture (1988-1990). Later, Raúl was sent to prison for his role on the assassination of the candidate Luis Donaldo Colosio in 1994, while Carlos Hank was investigated by the US government for his ties with drug trafficking cartels—although he was never charged. His son, Jorge Hank Rhon, was married to Roberto's daughter. Their son, Carlos Hank González is now GRUMA's vicepresident (CNNExpansión 2014).

[9] In 1982 the banks were nationalized by Miguel de la Madrid (1982-1988) in an effort to stabilize the economy after the debt crisis that forced the Mexican government to default.

order of magnitude, from 3.5 billion in 1989 to 33.3 billion in 1993 (Vos, Taylor, and Barros 2002). Credit from the now private banks also expanded quickly as optimism in the economy surged, interest rates lowered, and governmental controls relaxed. The bonanza lasted only a few years, however; rapid appreciation of the peso due to the inflow of capital, high default rates in private credits, and political instability (the assassination of a political candidate and the Zapatista uprising) led to capital outflow from portfolio investments (1994-1995). The result was one of Mexico's most serious economic crises, the first of the neoliberal era.

Aside from the disgraceful outcomes of the early reforms in the finance system for the economy as a whole, this period provided several opportunities for large firms like GRUMA, as is suggested by its impressive expansion. In 1990, GRUMA built the largest maize-flour plant in the world in Los Angeles, California.[10] That same year, the company expanded operations in Guatemala, El Salvador, Honduras, Nicaragua, and Venezuela. In 1992 it acquired 10% of Banorte, one of the largest banks in Mexico, and in 1996 it inaugurated Molinos Azteca in the US in association with Archer-Daniels-Midland Co., one of the largest food corporations in the world. In 1994, GRUMA went public and was listed on the Mexican Stock exchange, with shares traded on Wall Street starting in 1998. As the millennium opened, GRUMA was operating in 100 countries and four continents. In only five years, between 1991 and 1996, sales nearly doubled, increasing from $808 million to $1.54 billion (Rendón Trejo and Morales Alquicira 2008); they doubled again by 2006. At that point, GRUMA's market shares reached 75% in Mexico, 68% in Central America,

[10]This was not the first incursion of GRUMA outside of Mexico. Between 1973 and 1989, GRUMA launched operations in Costa Rica, and acquired Mission Foods, Guerreo brand, and ten milling plants in the US. However, the main period of expansion took place during the 1990s.

and 70% in the US.

GRUMA, in 1949, was the first company to produce and commercialize maize flour in large volumes. The possibility of producing a dry, non-perishable product was an important step for the consolidation of the industry, generation of scale economies, and relocation of processing plants from cities to grain source locations. The other way to produce tortilla was (and still is) by using wet *nixtamalized dough,* which as an industrial product had several disadvantages due to high transportation costs and perishability. Tortilla production in Mexico depends on thousands of small *tortillerías* (tortilla making plants) dispersed over urban and periurban areas. Before the advent of maize flour, *tortillerías* either had to produce their dough from scratch or buy it in the market. Preparing dough from raw maize had the advantage of lower transportation cost and low perishability, but the inconvenience of higher costs in the production of dough.[11] Buying dough eliminated all these intermediate steps, but was more expensive to transport and could not be stored. Maize flour emerged as a solution to these problems and generated substantial savings for tortilla producers. But market penetration of maize flour proceeded slowly. Until the end of the 1980s, flour-made *tortillas* accrued only 20% of the market and consumption was limited to large urban centers such as Mexico City. Nevertheless, over the following ten years, the maize flour industry took off, growing more than in the preceding 40 years. By 1998, 50% of the *tortillas* marketed in Mexico were already flour-made, and GRUMA was the largest supplier (MINSA 2001). This push was in part the result of a shift in support policies for the tortilla industry. Up to 1990, the government delivered maize at subsidized prices to *molinos de nixtamal* (nixtamal processing

[11] Preparation of maize dough is a laborious process. Maize needs to be cooked using an ancestral technique called nixtamalización, where maize grains are boiled for hours in water with lime to soften and remove the pericarp. Nixtamalized maize flour on the other hand only required mixing the flour with water. Savings in production of tortilla with flour was estimated at 20% compared with dough (Nafin 1982).

plants) and dough at subsidized prices for *tortillerías.* A few years before implementing full de-regulation of the supply chain, the government started to support the "modernization" of *tortillerías* by delivering subsidized maize flour (Nafin 1982) and new equipment to produce flour-made tortillas. The equipment and part of the flour granted by the government program to *tortillerías* were provided by GRUMA.

Much of GRUMA's expansion has taken place overseas (the Mexican market accounts for the only ¼ of their sales), especially in the US and Europe. However, as the top buyer of maize in Mexico and the lead firm within the maize-flour segment—almost a monopsony, its success certainly has had spillover effects upstream in the commodity chain. GRUMA built plants in the main production nodes across Mexico (e.g. northern Sinaloa, El Bajío) and import entry points (e.g. Veracruz, Progreso, Río Bravo). To secure its maize supply, GRUMA began to coordinate the supply chain and to sign contracts with producers at production nodes. In the 1990s, GRUMA helped to create what was known as Maize Clubs (Echánove Huacuja and Steffen Riedemann 2001), in which maize producers, banks, agrochemical suppliers and grain traders, technicians, research centers and GRUMA come together for information exchange and coordination. GRUMA acted as a source of collateral so producers could access credit from commercial banks (e.g. Banorte, their bank). Grain traders (*Comercializadoras de grano*) supplied inputs and technical assistance and served as a bridge between producers and GRUMA. They were in charge of collecting, storing and transporting the grain from production locations to processing plants. GRUMA was committed to purchasing all grain contracted, while the government provided technical assistance and subsidies through its various programs, which I mentioned before. These clubs did not last long, and it is not clear what their reach was. Nevertheless, they set an important precedent for the coordination structure we can observe today.

Contractual arrangements between producers and food processors became more important under the presidency of Vicente Fox (2000-2006), who established a minimum quota for grain purchases from domestic producers. Until 2008, before import quotas were fully eliminated, food processors were required to purchase between 10-25% of their corn requirements from domestic supply. As a result, corn production rapidly increased in Chihuahua, from 200,000 MT in 2001 to 1.45 million MT in 2005 (Rello and Saavedra 2007).

5.1.4 Cattle-ranching and the rise of the Mexican feedlot

Cattle-ranching is by far Mexico's most extensive agricultural activity. The activity had expanded in practically every biome, in particular after the 1950s when the Mexican government, the World Bank, USDA, the Inter-American Development Bank, and other international agencies began to support cattle production to develop frontier regions (Feder 1982). By 1980, an extensive grass-fed finishing system, involving more than 1 million km^2 or 60% of the country's land area (Durán, Medina, and Prado 2001, 138), supplied beef-cattle from dry, temperate, and tropical rangelands to the US and urban centers in Mexico, delivering carcasses to meat shops via municipal slaughterhouses (Figure 11). Due to historical circumstances and differences in natural resource endowments, the development of cattle ranching in Mexico followed a distinctive regionalization of production locations. Three main cattle production regions are typically distinguished (Reig, Feder, and Olivares 1982): arid north, temperate lands, and tropical lands (Table 5 and Figure 12). These zones are not only differentiated by their ecological characteristics but also by the ranching systems and market orientation.

Table 5. Characteristics of cattle production regions.

Region	**Optimal stocking rate** (ha/animal)[a]	**Herd size**[b]	**Feedlot herds** (%)	**Market**
Arid and Semiarid	25	8,837,967	13.65	US feedlots
Tropical	4	9,114,577	7.59	Domestic
Temperate	10	5,364,398	22.1	Domestic
Total/Average	13	23,316,942	13.23	

[a]Indicates the average minimum area required to raise one animal for one year on a sustainable basis. Based on estimations from Programa Determinación de Coeficientes de Agostadero, SAGARPA 2009. [b]Data from the agricultural census (INEGI 2007).

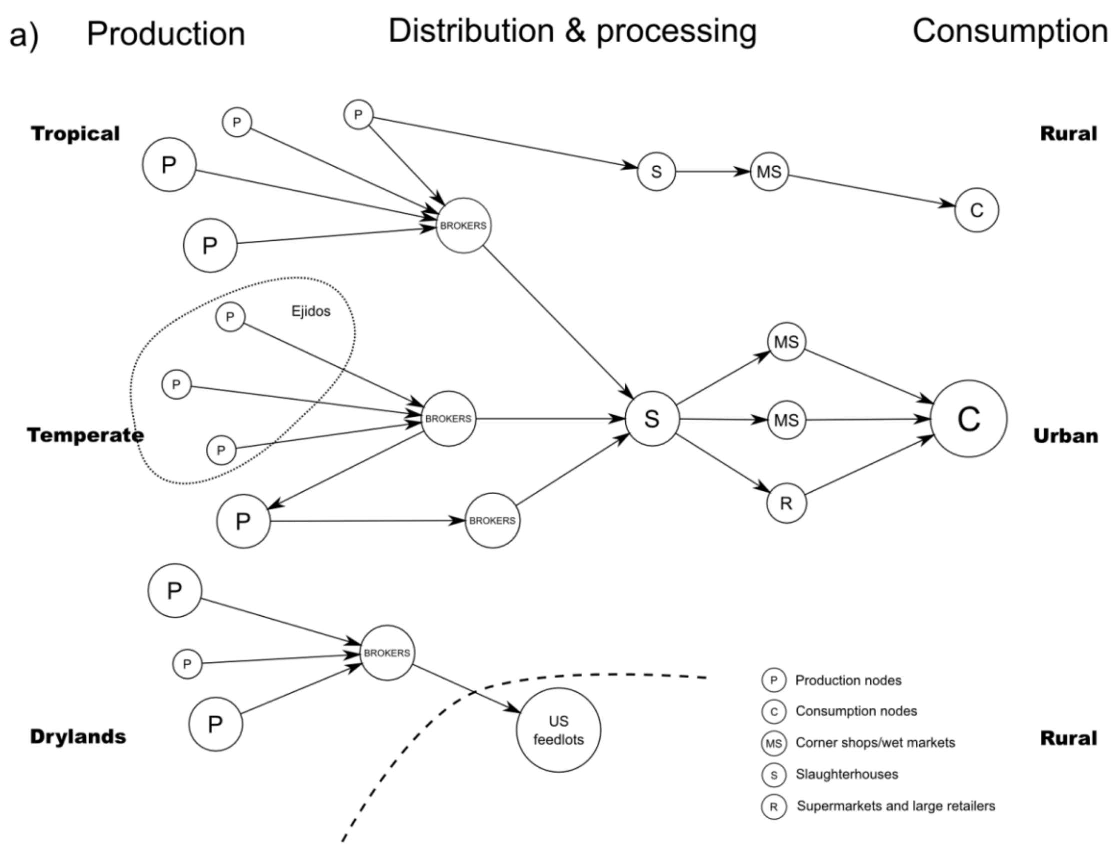
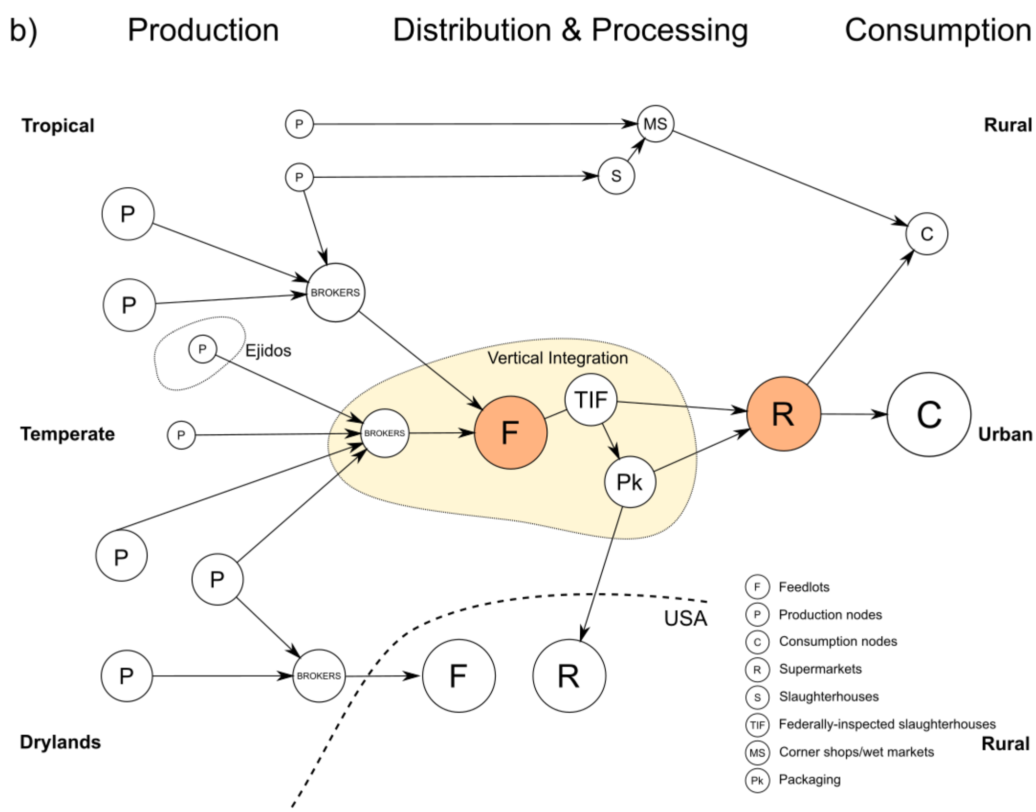


Figure 11. (a) Pre-reform period beef-cattle commodity chain and (b) post-reform period maize-cattle complex.

Figure 11. (cont'd).



Beef-cattle production in the arid north is specialized in the export of weaned calves and feeder cattle to the US; 97% of the approximately one million animals that cross the border every year are raised on these lands. Cattle breeds reflect the specialization. Here, pure breeds such as Hereford, Angus, and Charolais predominate. Given dry conditions, ranching is very extensive; a single animal may require as much as 80 ha per year. The region is subject to strict sanitary controls by the USDA, and most northern states are accredited by this agency to export live animals. Sonora, Chihuahua, Tamaulipas, and Coahuila are the main production and export centers. Over the last decade, fattening operations have rapidly expanded in the entire region, except in Sonora, which has the highest status in the USDA classification. To protect this status, the government regulates the import of calves from central and southern Mexico, a policy that has practically dismantled the state's feedlots.[12]

Figure 12. Beef cattle production regions. AL = Arid and semiarid lands; TL = Temperate lands; TRL = Dry and Humid Tropical Lands.

The temperate region has the oldest settlement history and the highest population density; it was the first region permanently transformed by the expansion of European livestock systems after the Spanish conquest (see Chapter 3, section 3.4). This region is an important producer of staples and feed grains. It is well connected with the rest of the country and enjoys good access to other agro-industrial enclaves and ports. Intensive crops, dairy farming, and livestock fattening predominate over extensive ranching operations. Two critical locations for beef-cattle production

[12]Interview with the Director of AMEG (July, 2015) and the former head of SAGARPA—Sonora (April 2015).

are the state of Queretaro and El Bajío region. The latter is also an important enclave for maize production.

The tropical region is the most recent area incorporated into cattle production. Expansion of pastures took off during the 1960s, with cattle herds doubling from 5 to nearly 11 million between 1960 and 1980. During the second half of the 20th century, this region provided a new frontier for agriculture, with agrarian reform as the main mechanism for transferring State lands to farmers. Most cattle production in the region is oriented to domestic markets, although an important export sector for both live cattle and meat has developed in recent years.

The transition to a neoliberal regime brought in radical changes to the livestock sector. One of the most significant adjustments was the rapid rise of intensive animal farming, including poultry, pork, and beef. For the beef industry, the feedlot system became a pivotal element. Two factors proved important here. First, liberalization of grain markets eliminated one of the main constraints on the expansion of the livestock sector. Second, changes in output markets, in particular, the rapid expansion of supermarkets, set new rules for quality and safety standards. These imposed significant barriers for beef produced through the "traditional" chain structure and cemented the feedlot system as the prime beef supplier for urban areas. As a new set of input-output relations evolved, feedlots, feed and grain suppliers, supermarkets and vertically-integrated corporations emerged as key actors in the chain's governance structure (Figure 11b).

The equivalent of MASECA within the beef chain is SuKarne, now a multinational that controls over 70% of the export market for Mexican Beef.

Unprecedented grain availability enabled the development of the feedlot system in Mexico, with characteristics and scale similar to the US feedlot. Domestic production of corn was at best marginal in Mexico during the pre-reform period, while most maize production was dedicated to human consumption. Nevertheless, the livestock sector exerted increasing pressure on demand for maize and other grains. From 1960 to 1979 the share of cropland area dedicated to feed crops increased from 3% to 17%, while imports of corn and other feed grains increased from an annual average of 0.3 million MT during the 1960s to 4.6 million MT during the 1970s (Pérez Espejo 1987). Diversion of grains from food to feed became an increasing concern so that in 1974 the government began a campaign to limit the use of maize for animal feed (CIMMYT 1981). After NAFTA, with most constraints on imports lifted, the livestock sector began to rely almost entirely on US corn. The feedlot system has increased in recent years, in particular since 2008. Between 2008 and 2014, large feedlots increased their herds by 64%, from 0.8 to 1.4 million animals. Today, aggregated demand for grains within the animal feed industry is 19.3 million MT, 53% of which is maize, 43% is sorghum, and only 1% other grains (CONAFAB 2015). Annual feed production is 30.1 million MT. Poultry production consumes nearly 50% (15.5 million MT), pork 16% (5 million MT), dairy 15% (4.8 million MT), beef cattle 11% (3.5 million MT), and others 7.4% (2.3 million MT).

One market advantage enjoyed by large buyers is their ability to purchase grain from different source nodes, as well as from global markets. Given the massive US grain surplus produced at subsidized costs, US maize is usually cheaper than domestic maize even considering transportation costs. Thus, the preferred source of grain for this sector is the US. In fact, the rise in livestock production has been accompanied by rising corn imports; in 2014 Mexico imported a total of 10.2 million MT of corn from the US, equivalent to 40% of Mexico's annual maize output, compared with less than 3 million MT during the early 1990s (USDA-ERS 2015).

Following NAFTA, traditional exports and staple crop prices fell drastically. Farmers and peasants shifted to maize, a crop with a large domestic market relatively protected by the State for political reasons. In particular, PROCAMPO was implemented in 1993 as a safety net for maize producers during the transition period before full liberalization; this did not occur until 2008 more than a decade after NAFTA went into effect. Maize, a long-standing symbol of Mexican national identity and food sovereignty, mobilized policies designed to prevent social unrest until long-term adjustments had been made.

The feedlot system has changed the nature of beef-cattle trade from source regions, both in qualitative and quantitative terms. The shift in the input mix has imposed a new cost structure, and the factors involved in feedlot location decisions are changing. Proximity to feed sources and urban markets seems to outweigh the importance of proximity to calf production regions, with feedlots concentrating in northern and central Mexico near agro-industrial enclaves (northern Sinaloa and El Bajío), or grain entry points (Tamaulipas, Veracruz, Yucatán). Nearly 80% of the animal inventories from the National Association of Feedlots (AMEG) locates in the arid northern states. Only 15% locates in temperate states, mostly in Michoacán, Jalisco, and Querétaro. Veracruz is the only tropical state with a significant share of AMEG inventories, accruing the remaining 5%. The participation of Veracruz in the feedlot sector is relatively recent. With the liberalization of grain markets, the Port of Veracruz has become a prime entry point for US corn, second only to the city of Reynosa in Tamaulipas. In general, higher risk of diseases in the humid tropics deters confined animal feeding operations. However, as noted by the owners of two feedlots and processing plants interviewed during my field work, access to cheap grains and proximity to a key export port compensates for higher investments in disease control. Additionally, feedlots located in Veracruz are closer to Tabasco, Chiapas, and Campeche, three important states for the production of feeder cattle. Meat packing plants locate near feedlots, near agricultural enclaves or entry points with good access to metropolitan areas. From here, frozen and fresh beef is delivered to large consumer centers via cold chains. Meat packing plants are built with joint capital from regional feedlot associations or by a single firm that provides services to nearby feedlots. In the case of large, vertically integrated firms, the same owner controls the feedlot and processing plant.

Long distance trade of live animals increased dramatically with the emergence of the feedlot system. Animals are now transported by truck as far as 2,300 miles (3,700 km), from Benemérito de las Américas, in the Mexico-Guatemala frontier, to Mexicali, in the US-Mexico border. Production of weaned calves and feeder cattle occurs in large part on the extensive pastures in tropical lands. Thus, in Mexico, beef production has compartmentalized into specialized segments. The old regionalization of beef-cattle is being replaced by a new geography, with regions specializing in different nodes of the chain structure. Calves are produced on pastures in tropical dry and humid biomes, often by small-scale producers. Production of feeder cattle also depends on extensive tropical pastures but tends to be undertaken by brokers or large ranchers who can collect animals from dispersed small holders producing only a few calves per year. Finally, brokers deliver feeder cattle to feedlots in central and northern Mexico. Figure 13 illustrates one of the main trade routes in Mexico, which involves trade flows between source regions in Chiapas and feedlots located in central and northern Mexico.

Figure 13. The figure shows one of the most important trade routes of feeder cattle. Numbers indicate the cumulative share of traded animals each route segment represent. Green areas are source municipios, maroon areas are destination municipios. For example, 50% of animal flows originate in Benemérito de las Américas, Chiapas. Palenque adds up another 28%. Thus, the aggregate contributions from these two municipios are 78%. Animal freights begin to deliver in Tabasco and Veracruz, but most animals are delivered to feedlots located in central and northern Mexico. About 29% feeder cattle ends up in the northeast (Nuevo Leon and San Luis Potosí), and nearly 60% flow towards central (Querétaro and Michoacán) and northern Mexico (Durango). Source: data from zoo-sanitary inspection points, provided by the secretary of agriculture of Chiapas (CFPP 2013).

In the past, animal trade consisted mostly of live cattle ready for slaughter delivered to municipal slaughterhouses located near metropolitan areas. Most large slaughterhouses were found in Mexico City and Mexico State. Around one-third of the trade consisted of calves delivered to pastures and feedlots in the center and north of the country (e.g. Queretaro, San Luis Potosí), and then sent back for slaughter in Mexico City and other metropolitan areas. Low integration, coordination, and regulation characterized the chain segments. One exception to this pattern was

Tabasco. With one of the largest slaughterhouses in the country, this state was a net importer of live cattle and an important supplier of carcasses to Mexico City. Today, the situation is quite different. More than 90% of the animals traded by three of the most important beef-cattle producers are delivered to feedlots, while the trade of animals ready for slaughter or stockering has decreased in absolute and relative terms (see Table 6).

The expansion of feedlots in Mexico has increased the extraction rate of animals from source nodes. Feedlots prefer younger animals that on average spend a year on pasture, 3–4 times less than the time spent by grass-fed finished animals. The weight at slaughter for grain-fed cattle in Mexico is 400–450 kg, compared with 600–700 kg for grass-fed animals. Finally, population growth and development of an important export sector are increasing the demand for Mexican beef. The combined effect has led to an increase in the demand for animals from pasture lands. But supplying them from traditional source regions has proved difficult due to low productivity of cow-calf systems and a contraction in the number of producers following neoliberal reform. As a consequence, average prices for young animals have increased over the last five years (see Figure 14).

Table 6. Mix of cattle exports from selected southern states 1979, 2012.

	1979[a]	**2012**[b,c]
Chiapas		
Total trade	150 (100)	665 (100)
Ready for slaughter	100 (67)	15 (2)
Fattening	50 (33)	635 (96)
Stockering		11 (2)
Tabasco		
Total trade	-10 (100)	299 (100)
Ready for slaughter	-10 (100)	9 (3)
Fattening	0	290 (97)
Stockering		1 (<1)
Veracruz		
Total trade	80 (100)	345 (100)
Ready for slaughter	50 (62)	25 (7)
Fattening	30 (38)	319 (92)
Stockering		2 (<1)

Figures in thousand animals. Numbers in parentheses indicate percentages. Negative figures indicate imports. Sources: a. Reig et al. 1982, p. 184. b. Área de Movilización. Comité de Fomento y Protección Pecuaria del Estado de Chiapas. c. Área de Movilización, Secretaría de Desarrollo Agropecuario, Rural y Pesca (SEDARPA).

5.1.5 Beef markets and the supermarket revolution.

An assessment of NAFTA's impacts on agriculture after 20 years found that trade between Mexico, the US and Canada increased 233%, while trade between Mexico and other non-NAFTA partners increased ten times. Trade in livestock and animal products tripled, from ~5 to 15 billion, while "[s]anitary cooperation … [and access to input markets] has facilitated the emergence of a larger feedlot sector" (Zahniser et al. 2015). This expansion of Mexican production and export did not take place all at once, however, particularly in the beef sector. Following the debt crisis in the 1980s, the beef industry was shocked by shortages in capital availability, resulting from cuts in government spending and credit, as well as wage contraction. Disinvestment in tropical regions where cattle ranching was the primary agricultural activity ranged between 65 to 81 percent in real terms between 1986 and 1990, while loans for livestock production from public banks fell 55 percent (Villafuerte Solís, García, and Meza 1997). A surge in US beef imports followed stagnation. Beef and veal imports from the US grew from a five-year average of 66 thousand metric tons in 1990-1995 to a five-year average of 272 thousand MT in 2005-2010 (USDA-ERS 2014).

This downward trend was ultimately interrupted by two crises. The first crisis was an outbreak of Bovine Spongiform Encephalopathy (BSE) reported in December 2003 in Washington, which resulted in 53 countries banning beef imports from the US, including primary markets in Mexico and Japan. This crisis was important for two reasons. First, traditional US clients (e.g., Japan and Korea) began to search for new supplies, with Mexico viewed as a good alternative since no case of Foot and Mouth Disease (FMD) had been reported since 1946, and no cases of BSE had ever been confirmed. The other reason was a ban that temporally halted Mexico's massive import of US beef and opened a window of opportunity for home-produced beef in domestic markets. The second crisis to favorably impact Mexico's beef sector was the 2008 US recession, which hit the Mexican economy severely and drove the peso from $10 to $15 pesos/dollar in only a few days. However, devaluation made US imports expensive and Mexican beef attractive not only for domestic consumers but also for low-income segments of the US market. The recession enabled the consolidation of an export phase with beef exports growing exponentially since then. In only a decade (2002–2012), Mexico shifted from a top beef importer of US beef to the fourth largest supplier for that same market. Exports grew from 12 thousand MT in 2005 to 114 thousand MT in 2013 (Figure 15). Imports reached their peak in 2008 and plummeted after that at 7% per year, while exports to the US have increased 86% every year. A flat balance of trade is projected for 2016. Today, Mexico exports beef to 13 countries in Asia, the Middle East, Eastern Europe and North America.

Another factor that enabled the growth of the Mexican feedlot system involves the so-called "supermarket revolution," the rapid expansion of foreign multinationals and capital in the retail sector in Mexico following the liberalization of capital markets and elimination of price controls for consumer goods in early 1990 (Reardon and Hopkins 2006). Initially, expansion of the retail sector resulted in rapid increases in beef imports from the US, with Mexico becoming the second largest market for US beef after Japan by the year 2000. Thus, the development of the beef industry after neoliberal reform, in particular after NAFTA, can be characterized by two main phases: (1) a phase of decline and stagnation in national production with a surge in beef imports lasting to 2003; and (2) a phase of recovery, expansion and consolidation that still continues today. Phase transitions were triggered by other symptoms of globalization: the spread of diseases and information and crises of accumulation.

Demand from supermarkets increased emphasis on food safety, and retailers required minimum standards to increase the shelf life of meat products. Multinational corporations such as WalMart applied to inventory management protocols, which included the quality and safety regulations of their home countries. Feedlots responded by integrating federally-inspected slaughterhouses (named *rastros TIF* after *"Tipo de Inspección Ferderal"*), packaging plants, and in some cases, sell points at one end of the chain and collection centers for live cattle at source nodes. These transformations occurred slowly during the 1990s but created the conditions that ultimately led to a strong sector.

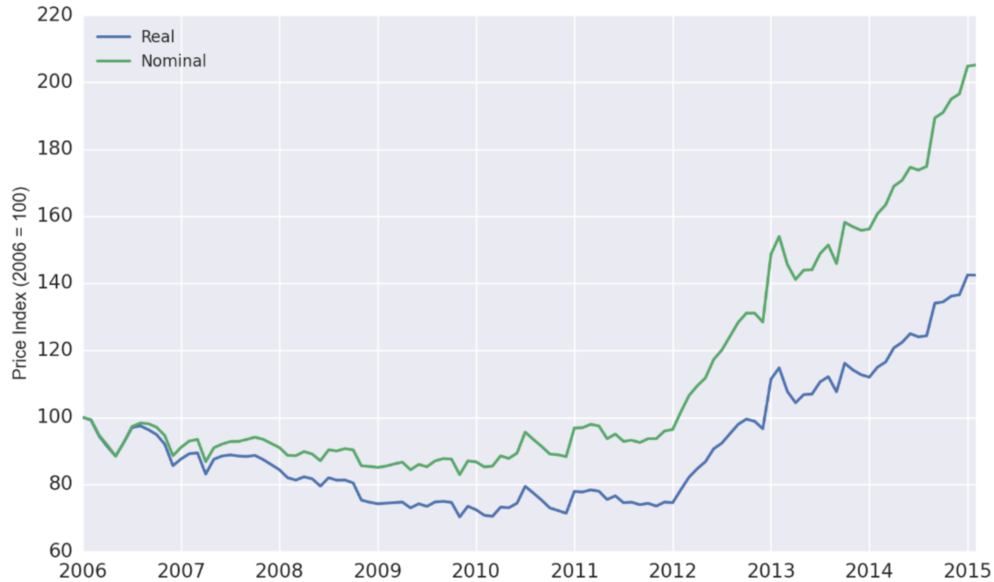


Figure 14. Price index for feeder cattle deflated by Consumer Price Index (1969-2015). Base year 2006 = 100. Price paid by feedlots for feeder cattle. Source: Asociación Mexicana de Engordadores de Ganado (AMEG).

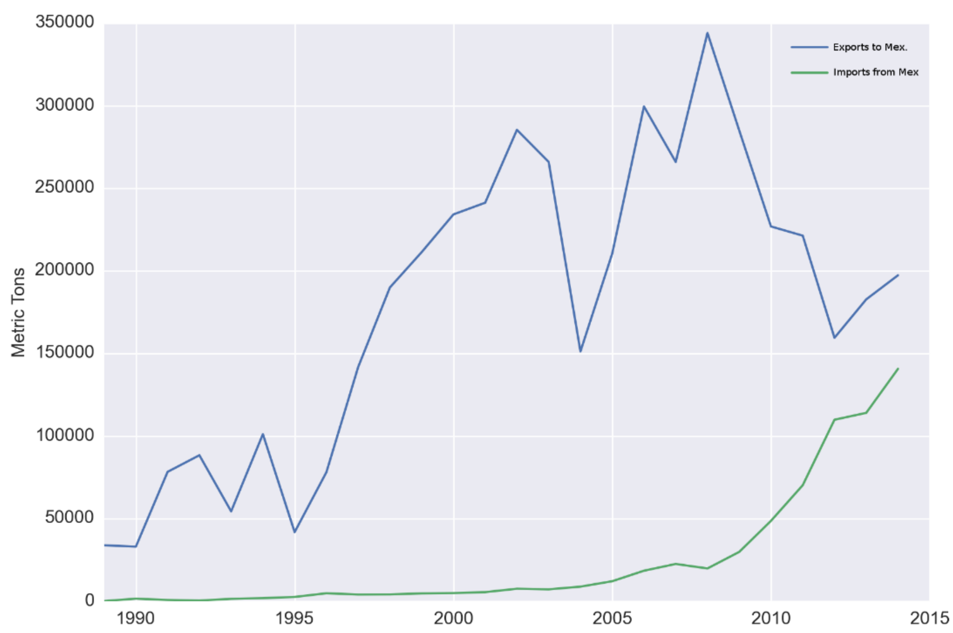


Figure 15. US-Mexico beef and veal trade. Source: USDA-ERS.

5.2 Chain spatial reconfigurations and land change

In previous sections of this chapter, I analyzed some relevant transformations in the M&B commodity chains. I explained why maize cropland did not decline in Mexico under the neoliberal regime, remaining relatively stable at about 8 million ha. At first glance, it might, therefore, seem that neoliberal reform has not produced much of a change in Mexico's LCR, at least with respect to maize. Such a conclusion would be highly misleading, as I now show.

5.2.1 Relocation and concentration of maize production

Cropland area devoted to maize declined in 57% of the *municipios*, a reduction equivalent to 1.8 million ha, between 1991 and 2007. However, cropland area increased in the other 40%, an areal increment of 1.9 million ha. Only 100 *municipios* concentrated more than 60% of the total cropland area. A map showing *municipios* with increasing (in dark pink) and decreasing (in green) cropland area is shown in Figure 16. To simplify and reveal the most important changes, only *municipios* with increments/decrements greater (smaller) than 2500/-2500 ha were colored dark pink or green. Both irrigated, and non-irrigated lands are aggregated. Figure 16 suggests that changes did not occur randomly in space and that spatial changes may be identified, with a concentration of maize cropland in few clusters, met by abandonment in others. But visual inspection is unreliable, and we need to assess such statement statistically.

Figure 17 shows maps from a univariate Local Moran's I applied to the difference in cropland area per *municipio*. Here, I present one analysis for non-irrigated lands (Figure 17a) and one for irrigated lands (Figure 17b). Although LISA analysis yields four types of local autocorrelation patterns (2 for positive and 2 for negative autocorrelation), I show only hot (HH clusters) and cold spots (LL clusters) for the sake of simplicity in the presentation. Only those *municipios* for which local autocorrelation was statistically significant ($p < 0.05$) are depicted. LISA maps confirm the existence of spatial structure: clusters of declining and clusters of increasing cropland area. The spatial structure of irrigated and rainfed production is also very different. Expansion of rainfed croplands concentrated in 4 large hotspots in (1) central Durango; (2) the states of Zacatecas, Aguascalientes, and Jalisco; (3) part of Michoacán and Guerrero; and (4) most of the Southern Yucatán Peninsula Region (Tabasco, northeastern Chiapas). Clusters of declining cropland area concentrated in northern Mexico (Chihuahua and Sonora), Tamaulipas-Nuevo León, and southern Chiapas. The HH region comprises 140 *municipios*, which together accrued 43% of the 1.9 million ha of new cropland. Here, average yields tripled during the period, increasing from 0.9 MT/ha to 2.6 MT/ha. However, yields were 30% lower than in the LL region in 2007 and 40% lower in 1991. This suggests that the shift of cropland from LL to HH occurred by the displacement of maize production from better quality to more marginal lands. One possible explanation for the increase in maize production in these areas is the increasing allocation of maize to grain-fed operations, and the semi-intensification of cattle-raising in the system of "stockering," a stage in which calves graze on pasture before entering the feedlot.

Relocation of irrigated lands reveals a more dramatic process. Irrigated maize production virtually flipped from the east to the northwest coast. In the HH region cropland area increased by 173,000 ha, a number substantially lower than the 470,000 ha lost in the LL region. Overall, irrigated lands dedicated to maize production declined by 15% over the study period. However, in this case, production relocated to highly productive lands, some with average yields of 12 MT/ha or more. In 2007 the HH clusters produced 67% of the maize off irrigated lands, whereas the LL clusters were responsible for 40% in 1991. My results stand in contrast with Sweeney et al. (2013), who used a different dataset to estimate that maize-planted area declined in rainfed lands at a rate of 120,000 ha/yr since 1980, but increased in irrigated lands at a rate of 49,000 ha/yr. For example, Sinaloa was not an important maize producer in 1980, but by 2011 this state alone supplied nearly 20 percent of the national output. Displacement of maize production to the west coast seems to be a result of competitive pressures with corn imports. The west has cost advantages for delivery of white maize to Guadalajara, Mexico City and Chiapas, while US corn has advantages in the Gulf states (see Table 7).

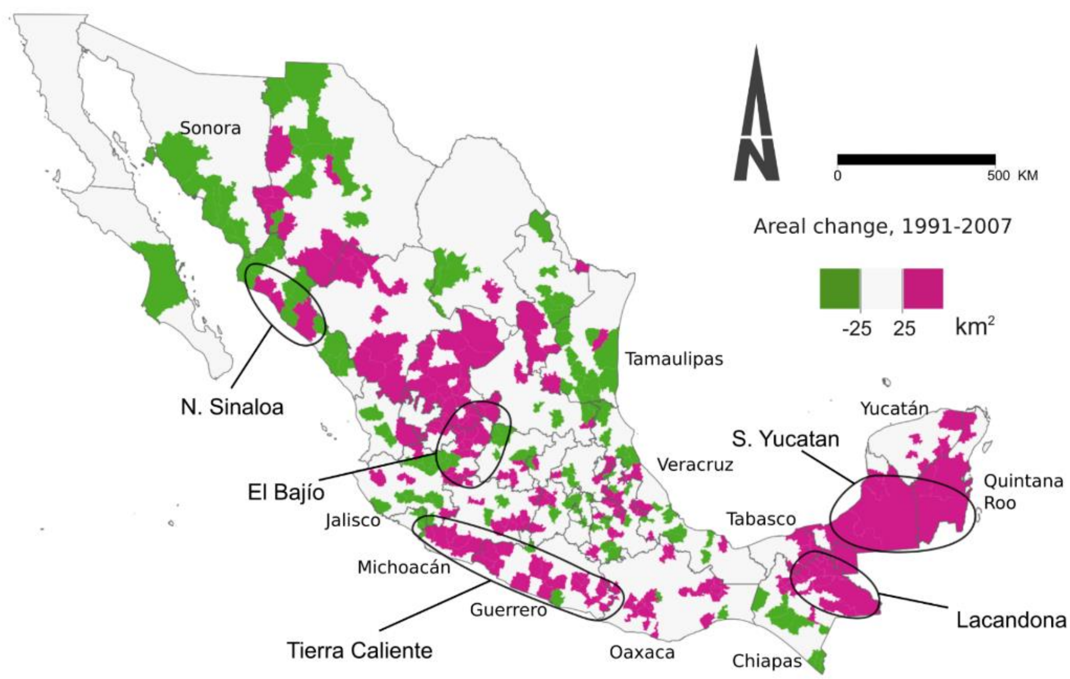


Figure 16. Changes in maize cropland area 1991 – 2007, Spring-Summer cycle

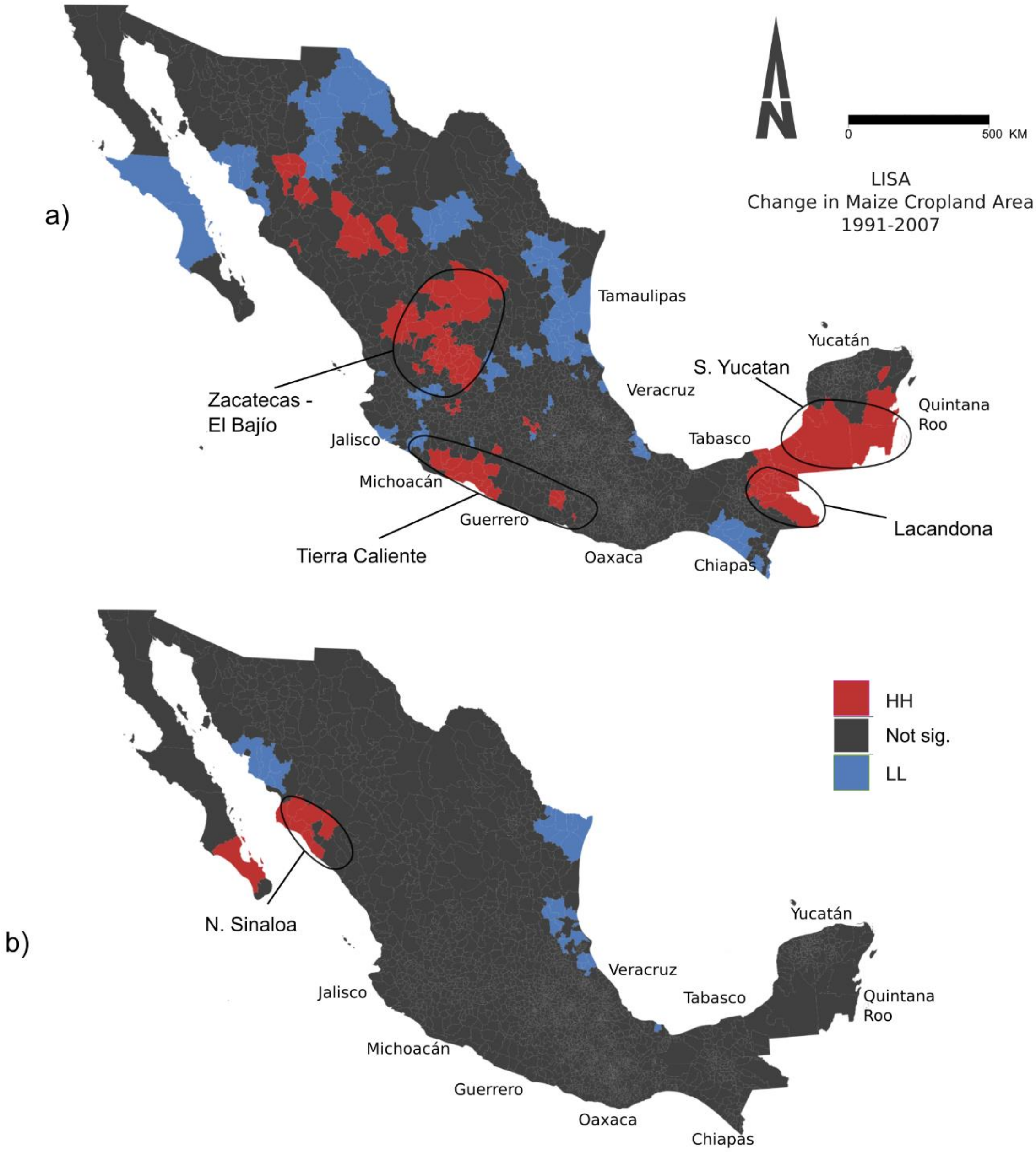


Figure 17. (a) LISA map for ΔMaize, Summer-Spring. (b) LISA ΔMaize, Fall-Winter.

Table 7. Transportation costs of maize from the Midwest (USA) and Sinaloa (Mexico) to selected destinations (USD/MT).

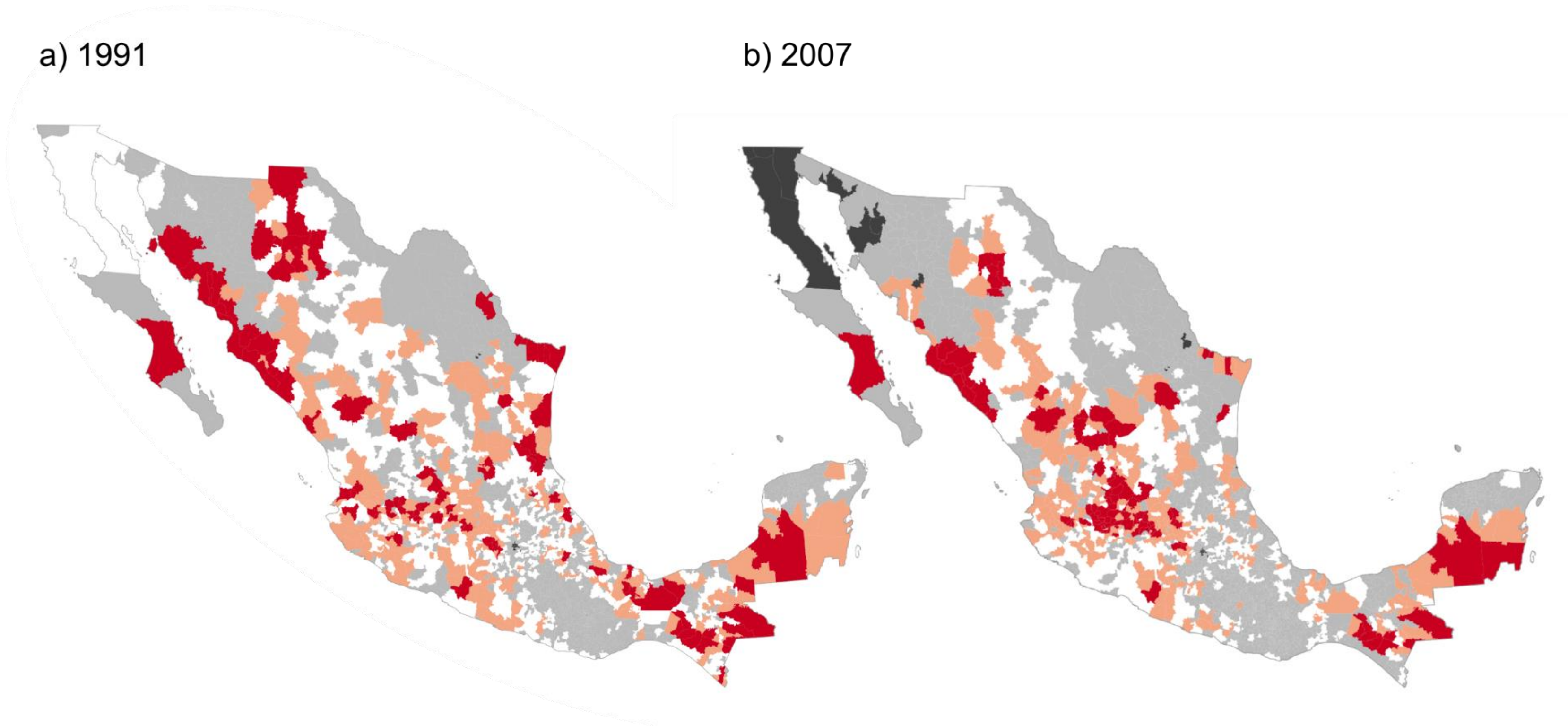
Origin	**Destination**	**Maritime**	**Terrestrial**	**Total**
USA (Midwest)	Altamira	34.00	53.30	43.65
	Cd. México	49.09	56.36	51.51
	Guadalajara	62.41	59.51	61.69
	Monterrey	50.90	43.25	45.80
	Progreso	49.30	-	49.30
	Tuxtla	71.40	-	71.40
Mexico (Sinaloa)	Guadalajara	34.00	36.90	35.45
	Progreso	53.80	132.10	92.95
	Tuxtla	51.80	104.90	78.35
Average		52.55	66.20	58.01

Source: Data from "*Estudio para determinar la estrategia de organización para internación de granos a través de los puertos Mexicanos. Puertos de México, Secretaría de Comunicaciones y Transportes, México, 2008*".

Did maize production (annual yields) follow the same spatial pattern? Figure 18 shows two Lorenz maps, a spatialized version of a Lorenz curve, of the distribution of maize output at the *municipio* level for 1991 and 2007. The table serves as the map legend and shows the distribution of maize output across the four groups. Group 2 includes Group 1; combined they add up to 75% of the national annual maize yields. Group 3 includes Group 2 and Group 1; combined they add up to 90%, and so on. The map legend also indicates the number of *municipios*, total production, and planted area of maize for each group. As can be seen, the national output of maize increased by a factor of 2.5, although planted area remained practically stable. This notable increase in productivity was the result of yield increases observed in most *municipios*, and in particular in a few agro-industrial enclaves such as northern Sinaloa and El Bajío. Mexico's maize production concentrated in fewer *municipios* and less land in 2007 than in 1991; for example, in 2007, Group

1 produced 12.8 MT, a quantity that is 1.25 times higher than the total maize output in 1991, using only 1/4 of the cropland area. Average yields in this group increased by a factor of 3.8, from 1.7 to 6.4 MT/ha. This trend is much stronger when considering irrigated croplands only (not shown). In this case, four *municipios* of northern Sinaloa concentrated half of the national maize output produced on irrigated lands and ten *municipios* of the same state concentrated 75% of this seasonal output. Yields on irrigated lands in *municipios* of Group 1 increased by a factor of 5, from 2.6 MT/ha to 12.3 MT/ha, during the period. The Gini coefficient confirms these findings. Not surprisingly, maize production was already concentrated in 1991 (G=0.71) and became even more so in 2007 with G = 0.77. Spatial concentration also increased over the analysis period, as indicated by Moran's I statistic. The spatial autocorrelation index increased 19% between 1991 and 2007, rising from 0.32 in 1991 to 0.38 in 2007. Both estimations were significant at 99% confidence interval.

Together, the spatial analysis confirms a trend towards spatial concentration; expansion of new lands for maize production and productivity increases tend to occur in a few clusters across Mexico. Two important processes characterized agricultural change following neoliberal reform: (1) *Municipios* in agro-industrial enclaves concentrated a higher share of the national grain output, and (2) spatial concentration or clustering of agricultural enclaves increased. These trends are consistent with the land sparing argument of FT theory, which suggest that industrialization of agriculture tends to increase spatial concentration in agriculture, a prerequisite for forest recovery.



Color code	*Production MT x 10^6 (%)*		*Municipios N*		*Cropland Area Ha x 10^6 (%)*	
	1991	**2007**	**1991**	**2007**	**1991**	**2007**
	5.1 (50)	12.8 (50)	177 (7)	97 (4)	3.0 (35)	2.1 (24)
	7.7 (75)	19.2 (75)	512 (21)	345 (14)	5.5 (64)	4.6 (54)
	9.2 (90)	23.1 (90)	955 (40)	738 (31)	7.2 (83)	6.6 (77)
	10.2 (100)	25.6 (100)	2383 (100)	2383 (100)	8.6 (100)	8.7 (100)
	No data					

Figure 18. Lorenz Maps of the distribution of maize output 1991-2007. Source: Censos Agropecuarios 1991, 2007 (INEGI).

5.2.2 Relocation and concentration of beef-cattle production

The dynamics of change in cattle stocks across the country are consistent with the thesis pointing to the emergence of the feedlot as a key component in the beef commodity chain. The spatial analysis provides evidence suggesting that cattle herds concentrated in a few *municipios* in the north of the country, in small clusters near important grain production/distribution nodes. During the period analyzed, animal stocks declined in most parts of the country. From 1991 to 2007, total animal stocks decreased from 24.6 to 23.3 million, although the dynamic was spatially heterogeneous. Herds shrunk in 70% (1,690) of *municipios*, totaling a reduction of 4.2 million animals. The rest of the 698 *municipios* partially compensated this loss by regaining a total of 2.9 million animals, with only 39 *municipios* concentrating half of that increment. Figure 19 show changes in cattle herds observed during the study period. As before, dark pink represents *municipios* where cattle herds are declining and green areas where animal numbers are increasing. This time, the Figure distinguish between confined herds or feedlots—the intensive part (Figure 19a) and herds raised on pastures—the extensive part (Figure 19b). The figure suggests that the cattle population was very dynamic during the period in question, with large areas losing ground (especially the extensive sector) and some regions concentrating production (especially the intensive portion). In Figure 19b we observe clusters of high concentration across central (e.g. El Bajío) and northern Mexico (e.g. Comarca Lagunera, northern Sinaloa). The extensive sector expands in southern Mexico (e.g. Southern Yucatán Peninsula Region, Chimalapas), the south Pacific Coast in Michoacán, Guerrero, and Oaxaca. In the north, cattle herds expand in several *municipios* across a belt that goes from northern Nuevo León to the Pacific Coast of Jalisco, as well as Sinaloa, Sonora, and Durango.

While the aspatial form of concentration increased, the spatial form decreased. Using the Gini coefficient, again as a measure of concentration, we observe that G increased from 0.77 in 1991 to 0.87 in 2007 in the intensive case and 0.71 and 0.74, respectively, in the extensive case. Spatial concentration, as measured by Moran's I, declined from 0.36 in 1991 to 0.16 in 2007 for confined herds, and from 0.55 to 0.40 for pasture-dependent stocks. These findings suggest a reduction of land-dependent management. Feedlots require little land but large capital investments, so locations are conditioned more by the technology and input mix than by the availability of cheap land. Increased availability of grains and feeds may have also reduced dependence on large landholdings by non-confined ranching operations.

5.2.3 Cattle trade from Central America

The expansion of the feedlot system also explains new patterns of animal trade and animal smuggling from Central America, a phenomenon with significant implications for land change in Mexico and its southern neighbors.

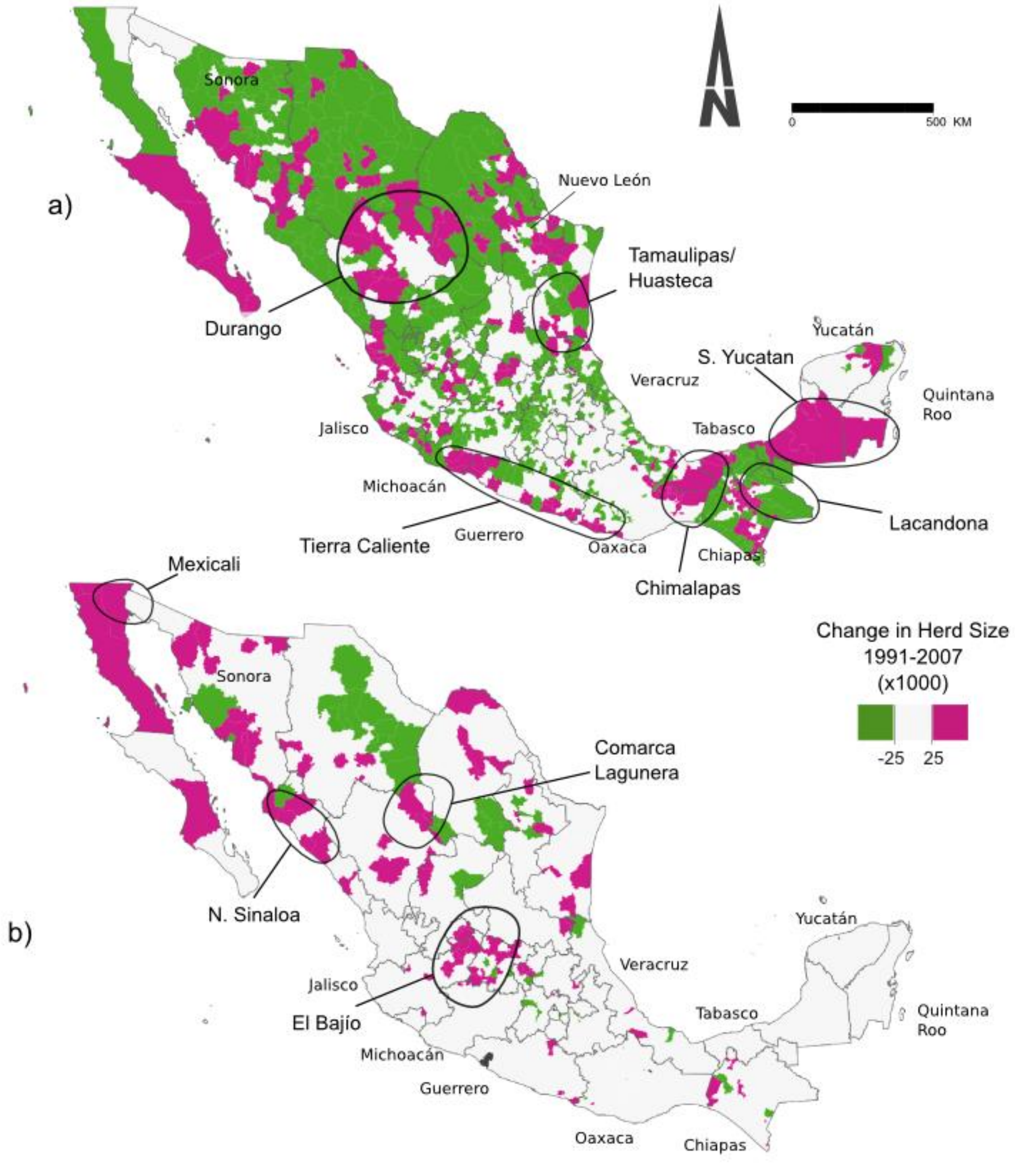


Figure 19. (a) Cattle herds and (b) Confined cattle herds per municipio. Source: Agricultural Census 1991 and 2007.

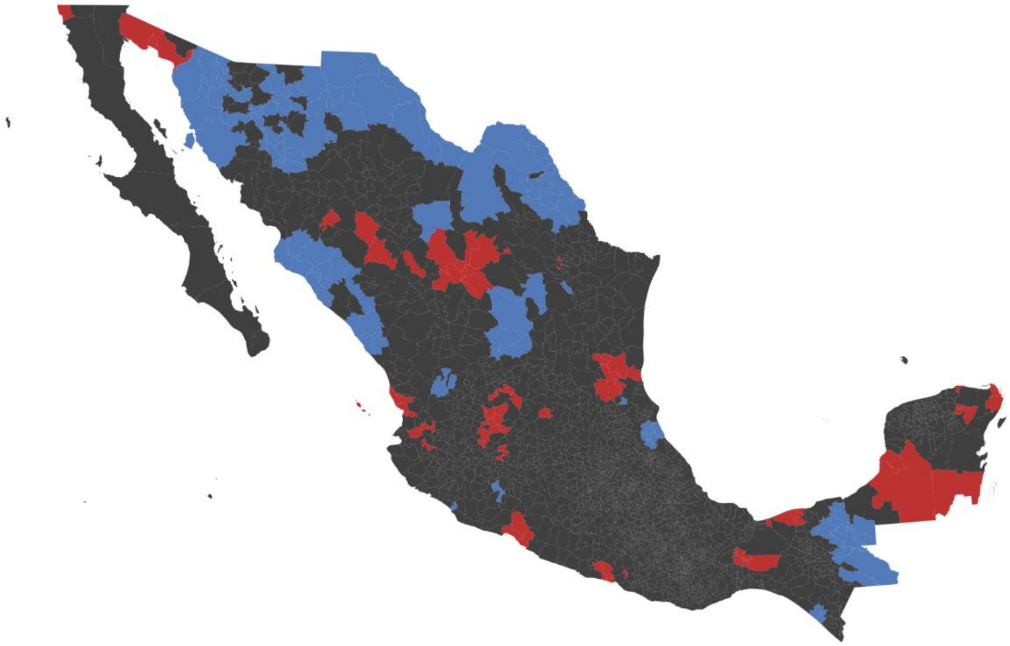


Figure 20. LISA maps for changes in cattle herds 1991-2007.

In 2014, between 700 and 800 thousand animals crossed into Mexico from Guatemala to supply the growing feedlot sector, almost the same number of live cattle exported from Mexico to the US that same year. Between 2008 and 2014, the number of animals supplied by the southern states of Veracruz, Chiapas, Tabasco, Campeche, Quintana Roo, and Yucatán increased from 1.2 to 2.3 million, more than 40% of the 5.5 million cattle slaughtered by the beef industry annually. However, the increment in the annual production of animals did not occur evenly over space. Again, to detect statistically significant clusters and identify areas of high contribution to observed increases in cattle extraction rates, a univariate local Moran's I was employed (Anselin 1995). Figure 21 shows results, where a significant cluster of *municipios* along or near the Mexico-Guatemala border showing abnormally high extraction rates is observed. The most important entry points for smuggled cattle from Guatemala fall within this group. Table 8 shows raw numbers comparing herd increases in this cluster of *municipios* and the rest of the region. Here, note that herds within the cluster increased at an annual rate of 0.53 percent, thirteen times faster than *municipios* outside that area. By 2014, 46% of the cattle mobilized from southern Mexico to other parts of the country came from these 13 *municipios* alone, and 98% of these animals were delivered to feedlots. Roughly 1/4 of the annual demand for feeder cattle in 2014 was supplied by Central American low weight animals. These findings demonstrate the pre-eminence of the feedlot system in the emergence of a cattle trade network involving Mexico and Central America.

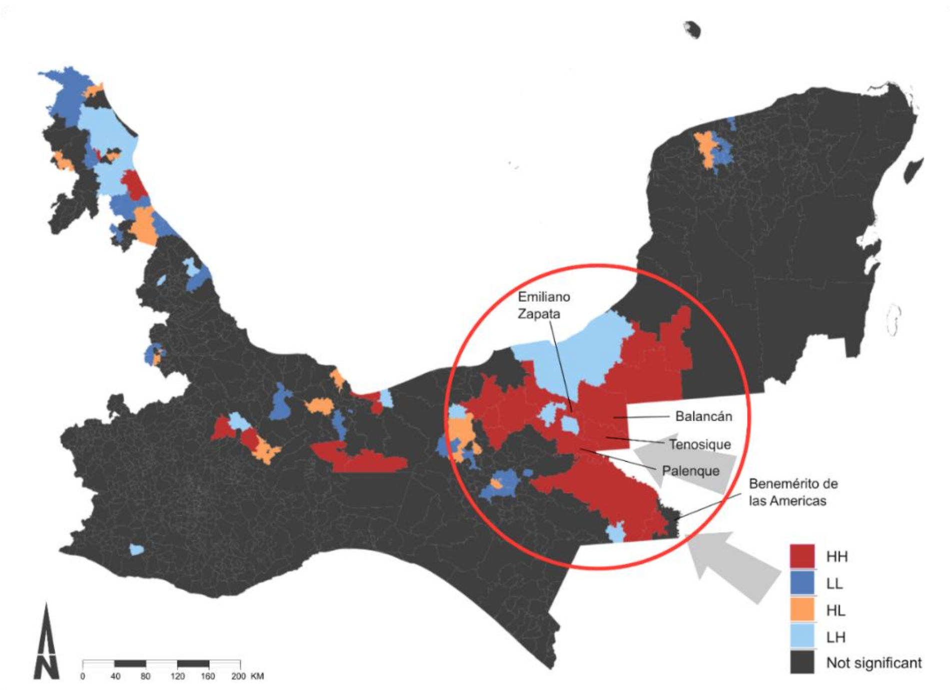


Figure 21. LISA map of the average increase in annual extraction of cattle from Mexican Southern municipios. Change rates were estimated using increase (decrease) of animals per square kilometer. Red areas indicate significant clusters of municipios with high increasing rates of extraction. Only municipios clustered at a significant pseudo $p < 0.05$ are shown. Gray arrows indicate entry points for smuggled cattle from Guatemala. See text for explanation.

Table 8. Increase in cattle herds traded from Southern Mexico, 2008-2014.

Year	***Cluster**	**%**	**Southern Mexico**
2008	225,709	19	1,160,254
2009	290,225	21	1,351,316
2010	481,530	29	1,673,305
2011	562,992	31	1,799,405
2012	831,933	40	2,084,199
2013	636,895	40	1,584,502
2014	1,062,151	46	2,304,341
Annual Change Rate	0.53		0.14

*Refers to the HH LISA cluster circled in Figure 21.

During field work conducted in 2013, the researcher visited one of the main entry points for smuggled cattle, the *municipio* Benemérito de las Américas[13] located in eastern Chiapas. Unfortunately, this trip coincided with an antidrug and anti-smuggling operation by the Mexican army, and all cattle trade halted at the time. Also, people were afraid to speak openly about cattle smuggling. The researcher managed to talk with ranchers in a neighboring *municipio* (one of them a rancher working for the company SuKarne), truck drivers, and personnel from two local cattlemen associations. These conversations indicated two ways whereby Central American cattle end up as part of the Mexican herd. First, buyers of feeder cattle assemble freight at the border, prepare the animals for travel (apply antibiotics and other medications), register them in the local association, and certify animal health status in offices of SENASICA (*Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria),* the national authority for animal health and food safety. A veterinary specialist from the feedlots then arranges the deal with middlemen. Once they

[13]Local Moran's I for this *municipio* was not statistically significant, and thus was not labeled as part of the circled cluster in Figure 19. The reason for this is because an extremely abnormal increase in the extraction rate makes this *municipio* an outlier within outliers. This *municipio* alone accounts for 38% of the animals sourced from the cluster. For this reason, for all estimations that I report from the "cluster" include this *municipio* too.

receive their animal stock, the buyers verify health status, apply a cocktail of medications, castrate with implant, and apply for a certificate from SENASICA authorities. The animals are delivered immediately to the feedlots. The second approach involves low weight weaned calves bought by local ranchers for stockering. Here, large capitalized ranchers with own capital or in contract with large feedlot companies concentrate land and cattle by subcontracting other ranchers or by renting pastures. Animals smuggled from Central America are pasture-fed for 3-6 months, depending on initial age and weight. Once they reach 200-280 kg, they are sold as feeder cattle to the feedlots.

Looking only at the agricultural census data, it appears that the Lacandona region in eastern Chiapas is becoming less important to the cattle chain. Nevertheless, half the production of calves delivered to other states originates in this region, and its participation has increased over the last decade (see next section). This apparent contradiction is again explained by a large number of animals smuggled from Central America. The Lacandona has become a transient region in the trade between Central America and Mexico.

5.2.4 Land change effects

Table 9 depicts conversions, presumably to agriculture, as well as forest loss due to logging across the forest biomes during the last 30 years. As can be seen, the data effectively partition LC for the pre-reform and post-reform periods, with deforestation diminishing in intensity since 1990, consistent with a shifting LCR. The periodization of the table indicates uniformly strong deforestation processes between 1980 and 1990, after which conversion to agriculture declines for all biome types. By the 2000s, significant variations emerge across biomes, with high and low rates of conversion of tropical forest and temperate forests, respectively. Regional assessments also confirm a downward trend of forest loss (Bray and Klepeis 2005; Vaca et al. 2012).

Table 9. Land change 1980–2012.

Biome	**1980/93**	**1993/02**	**2002/12**
All	669 (−8.4)	652 (−2.5)	640 (−1.9)
Temperate	340 (−3.4)	336 (−1.1)	336 (−0.13)
Tropical Humid	109 (−13.5)	104 (−4.1)	102 (−2.3)
Tropical Dry	219 (−14.7)	211 (−4.1)	201 (−4.7)

All figures in thousand square kilometers. Source: Data from Series de Uso de Suelo y Vegetación I (1980), (1993) II, (2002) III & V (2012) INEGI.

To this point, the dissertation has explored the role of commodity chains and neoliberal reform on Mexican LC. The analysis that follows considers how changes in source nodes for M&B, presented in Figure 10a-b and Figure 11a-b, relate to LC for a period bracketing the implementation of NAFTA. To this end, Figure 22 presents land change data in map form for 1993 to 2007, close to the period reflecting agricultural change (1991-2007); The fourteen-year overlap is sufficient to illuminate the hypothesized linkages. NAFTA enter into force until 1994 and so associated impacts on commodity chains likely manifested towards the end of the 1991–2007 analysis period. Also, significant economic impacts may not have occurred until later given lag times in institutional change and implementation. For example, the dismantling of the parastatal system waits until the 1990s, with the privatization of storage, processing, and distribution facilities occurring as late as 1995–1999 (Yúñez–Naude 2003). Cuts in agricultural credit and the elimination of input subsidies and price supports begin early in the period (de Janvry et al. 1997; Villafuerte Solís, García, and Meza 1997; Yúñez-Naude and Barceinas 2002). Nevertheless, a long-term policy process was at work beginning with GATT in 1986.

The geographic pattern of LC reveals the emergence of definite deforestation hotspots along the Pacific Coast, southeastern Mexico, and the Yucatán Peninsula. These are found primarily in the tropical dry and humid biomes. Forest transition crops up mostly in temperate areas and the dry lands of central and northern Mexico, although some are noticeable in coastal zones along the Gulf of Mexico. Figure 22 also shows six deforestation hotspots, where clusters of *municipios* are circled as in Figures 16 and 19. Comparing the agricultural and ΔLC maps results in strong spatial overlap. The degree of correspondence between deforestation clusters and agricultural expansion varies between the north and south and between maize and cattle, with a weaker agreement in the north and with maize. Northern maize production is more intensive, as in the state of Sinaloa, with the highest yields per ha across Mexico as mentioned above. Moving south, the correspondence between high deforestation *municipios* and high cropland expansion increases; southern *municipios* have more extensive agriculture and a higher proportion of forest at risk for clearance. The spatial pattern of change in cattle inventories is also more consistent, reflecting the fact that cattle-raising in the northern drylands, as well as in the tropical south, is extensive. Once again, correspondence is lower in the north, an effect probably related to the fact that most feedlots locate in this portion of the country.

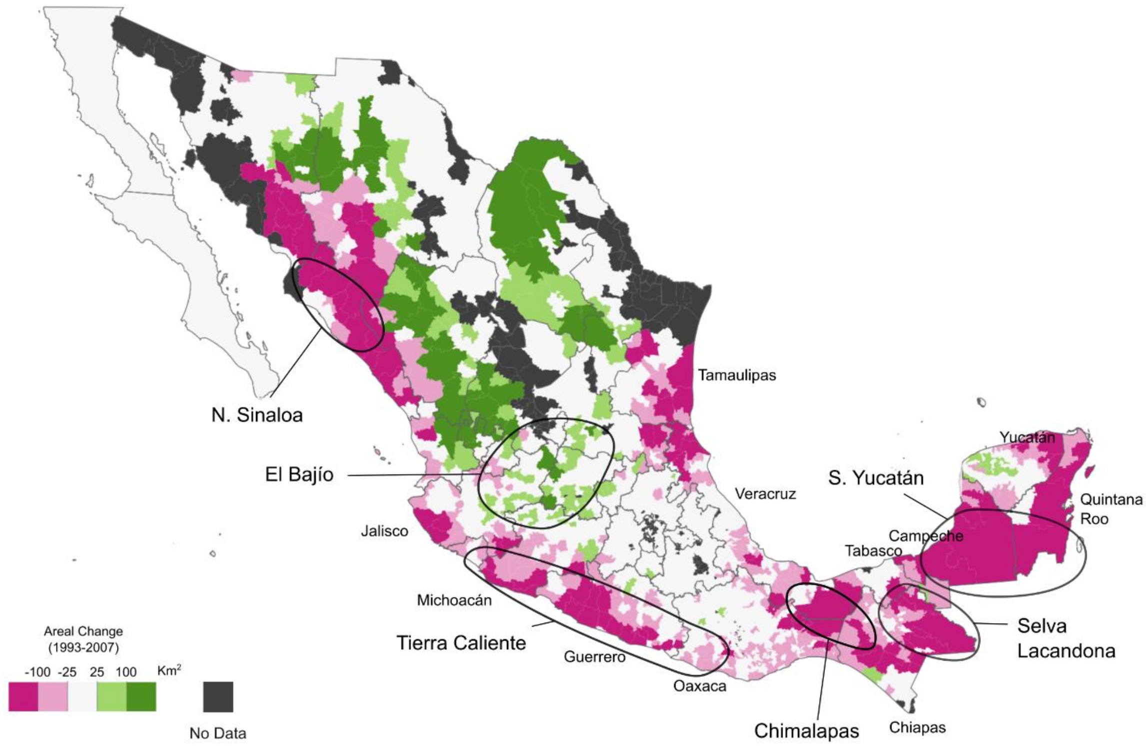


Figure 22. Changes in forest cover 1990-2007. Source: Serie II and Serie V (INEGI).

5.3 Econometric modeling

5.3.1 Model selection

Following Anselin (1988), model selection begins with a standard OLS regression, then uses a sequence of diagnostics to arrive at an appropriate spatial specification in case spatial autocorrelation is an issue.

Aspatial OLS results show highly significant coefficients, although the goodness of fit is small; the model explains only 14% of the variance of the dependent variable. Moreover, the model fails in all diagnostic tests. Both the Breusch-Pagan and Koenker-Bassett tests fail to reject the null of non-constant variance in the regression residuals. More importantly, spatial dependence is also present, as highly significant Lagrangian multipliers for the spatial lag and error models suggest. In light of these results, spatial error (SEM), spatial lag (SAR), and spatial Durbin (SDM) models were tested. Given the presence of heteroskedasticity, robust estimators were chosen over maximum likelihood methods.

Results point to SEM as the preferred model specification. None of the coefficients in the robust SAR were significant at the 5% level. The significance of the robust SEM regression coefficients also dropped, but some predictors remained significant at the 5% level. The SDM returned results similar to the SEM, suggesting that the latter is again the best specification. Following Anselin and Rey (2014), if increasing model complexity does not improve parameter estimation, as was the case here, the simpler form should be preferred. As shall be discussed, partitioning observations into spatial regimes also add explanatory power.

5.3.2 Regression results

In section 5.2, I point out that the spatial pattern of increase/decline of maize cropland and cattle herds (shown in Figures 16 and 19) matches the spatial pattern of increase/decline in forest cover (Figure 22). The econometric analysis presented here provides statistical confirmation that both *ΔCattle* and *ΔMaizeSS* explain LC in post-reform Mexico's forest, taking *municipio* areal extent and population growth as control variables. Table 10 reports summary statistics for model variables.

Four SEM models were estimated using the methodology outlined in Section 4.4: Standard robust SEM (Column 2), pooled SEM with partition on *ΔCattle* clusters (Column 3), pooled SEM with partition on *ΔMaize* clusters (Column 4), and pooled SEM with partition on both *ΔCattle* and

ΔMaize clusters (Column 5). Chow test results, summarized in Table 11, confirm that significant differences in parameter estimations exist across data partitions, and thus when spatial structure is accounted for, a single model does not suffice to describe the relationship between *ΔL* predictors and LC across Mexico. Columns 3-5 of Table 12 summarizes additional results for pooled SEM estimations.

Table 10. Summary statistics for model variables

Variable	**Units**	**N**	**Mean**	**SD**	**Min**	**Max**
ΔForest	Hectares	2,078	-1,638	9,860	-164,809	54,923
ΔMaizeSS	Hectares	2,398	262	3,307	-19,011	77,847
ΔMaizeFW	Hectares	2,398	-239	2,230	-35,044	59,977
ΔCattle	Herd size	2,398	-540	8,074	-78,932	189,895
ΔPopulation	Inhabitants	2,398	9,013	39,542	-115,587	736,611
Area	Hectares	2,398	81,578	224,231	221	5,327,169

Note that all model specifications incorporate the same set of independent variables. Also, maize is defined for both rainfed and irrigated production systems separately. Furthermore, all variables are in their original measurement units, which make interpretation of coefficients straightforward. For example, the robust SEM model (column 2; Table 11) shows that on average increase (decrease) of one animal unit results in the loss (gain) of 0.31 ha of forest. A higher negative coefficient for *ΔMaizeSS* suggests that expansion of summer-spring cropland area has a higher impact on forest than cattle herds. However, this variable was significant only at the 10% level. Model results are affected by a small, but significant ($p < 0.05$), size effect. Pooled SEM provides parameter estimations for two data partitions (or regimes if we use the econometric term), in our case one subset containing all *municipios* pertaining to *ΔCattle* (or *ΔMaize*) LL and HH clusters, as described in section 5.2.1 and 5.2.2, and one subset with all *municipios* outside these areas. As explained, LL/HH clusters correspond to contiguous *municipios* with highly dynamic land use trajectories, i.e. large positive (HH clusters) or negative (LL clusters) changes in cattle inventories and/or maize cropland area, presumably resulting from M&B commodity chain restructuring.

Table 11. Chow test diagnostics.

	Pooled SEM		
Coefficient	**(ΔCattle)**	**(ΔMaize)**	**(ΔCattle + ΔMaize)**
Constant	1.576 (0.2093)	11.686 (0.0006)	1.076 (0.2995)
ΔMaize			
Fall Winter	0.007 (0.9349)	5.125 (0.0230)	0.007 (0.9346)
Spring-Summer	20.650 (0.0000)	3.367 (0.0236)	5.464 (0.0194)
ΔCattle	7.732 (0.0054)	0.063 (0.8063)	0.318 (0.5728)
ΔPopulation	0.935 (0.3337)	1.901 (0.1680)	1.904 (0.1676)
Area	0.167 (0.6831)	4.414 (0.0356)	0.978 (0.3227)
Global test	30.696 (0.0000)	22.051 (0.0012)	13.912 (0.0306)

Table 12. Robust SEM and pooled robust SEM results

	Robust SEM	Pooled SEM (ΔCattle)	Pooled SEM (ΔMaize)	Pooled SEM (ΔCattle + ΔMaize)
			HH/LL Clusters	
Constant	-1983.894 (0.0148)	-3471.698 (0.0387)	1554.704 (0.2112)	-2742.597 (0.0253)
ΔMaize (ha)				
Fall-Winter	0.395 (0.2605)	0.456 (0.2139)	2.236 (0.0154)	0.440 (0.4333)
Spring-Summer	-0.435 (0.0825)	-1.234 (0.0000)	-0.527 (0.0190)	-0.634 (0.0223)
ΔCattle (herd size)	-0.309 (0.0021)	-0.020 (0.8230)	-0.288 (0.0089)	-0.263 (0.0152)
ΔPopulation	-0.003 (0.5754)	-0.009 (0.3180)	-0.026 (0.2008)	-0.012 (0.2108)
Area (ha)	-0.008 (0.0459)	-0.007 (0.3638)	-0.016 (0.0144)	-0.001 (0.0883)
			All other *municipios*	
Constant		-1516.069 (0.0065)	-2134.360 (0.0006)	-1750.866 (0.0060)
ΔMaize (ha)				
Fall-Winter		0.495 (0.1194)	0.096 (0.7384)	0.390 (0.1769)
Spring-Summer		0.234 (0.0572)	-0.045 (0.7501)	-0.060 (0.6197)
ΔCattle (herd size)		-0.403 (0.0001)	-0.334 (0.0300)	-0.364 (0.0107)
ΔPopulation		0.002 (0.7267)	-0.002 (0.5575)	0.004 (0.4909)
Area (ha)		-0.004 (0.1098)	-0.002 (0.5558)	-0.004 (0.0400)
λ	0.836 (0.0000)	0.796 (0.0000)	0.813 (0.0000)	0.823 (0.0000)
Pseudo-R^2	0.145	0.245	0.2332	0.170
N	2398	2398 ($n_{cluster}$ = 205)	2398 ($n_{cluster}$ = 270)	2398 ($n_{cluster}$ = 408)

Grayed out = not significant at the 5% level. *p* values in parenthesis.

5.3.3 Discussion

A negative coefficient in the various versions of the SEM estimation indicates that deforestation increases (or forest transition decreases) with *municipio* size. This result may reflect the fact that forest frontiers tend to locate in large *municipios,* where population density is low and extensive agricultural operations predominate, whereas forest transitions tend to occur near densely populated areas with intensive agriculture, where *municipios* are smaller. The spatial error component (λ) tends to be large and highly significant, indicating that the models omit other important causal factors; low R^2 is also a potential result of model misspecification. LC is a complex phenomenon with multiple causal factors, so results should be interpreted with this in mind. Nevertheless, given the large sample size, estimation of the partial effects is expected to be accurate (Wooldridge 2008). Although the models are not perfect, the findings confirm the importance of M&B land use dynamics in Mexico's post-reform LC. The pooled model specifications aim to shed additional light in this direction.

The pooled SEM specification is indicated by the diagnostics (Table 11) and theory suggests improved results. Given such, the formulation enables an assessment of the relationship between agricultural change and LC in regions undergoing different land use transitions. Also, data partitions control for heteroskedasticity resulting from large error variances associated with highly variable *municipio* size. In fact, the pooled SEM specification improved both parameter estimations and R^2, thereby shedding additional light on the issues. Here, the most significant differences arise when *ΔCattle* clusters are used. Interestingly, this pooled model results in even higher significant differences in *ΔMaizeSS* coefficients. When the partition is based on *ΔMaize* clusters (column 2, Table 11) both *ΔMaizeSS* and *ΔMaizeFW* coefficients are significantly different within and outside clusters. Here, significant differences for *municipio* area coefficients are also observed. Unexpectedly, in the pooled version that combine *ΔCattle* and *ΔMaize* clusters only *ΔMaizeSS* coefficients are significantly different. Together, these results suggest that *ΔCattle* clusters are the ones which best describes the spatial heterogeneity present in the data.

Accounting for spatial heterogeneity improved estimation of both *ΔCattle* and *ΔMaizeSS* effects, although the importance of each predictor was different for each partition. Coefficient stability and significance for *ΔCattle* across models are remarkable. In P1, the coefficient for *ΔCattle* increased to 0.41 and was highly significant with the expected sign, but only for the unclustered subset of *municipios*. No other ΔL predictor or control variable was significant for this subset. On the other hand, within clusters, only *ΔMaizeSS* was significant, highly significant with a large negative coefficient. This is an interesting result since the clustered subset consists of dynamic *municipios* (n = 204) with large increases in cattle herds between 1991 and 2007. Cattle herds in HH *municipios* increased at an annual rate of 3%, a number that contrasts with the national average of -0.33%. Herds within LL clusters, on the other hand, decreased at an annual rate of -2%. Figure 20 shows the LISA map for *ΔCattle*. Roughly, clusters in this figure correspond to the dark pink (increases) and green (decreases) *municipios* of Figure 16.

Although the pooled models implemented do not allow estimation of spillover effects between cattle herds and maize cropland expansion, the finding that changes in maize cropland area explain LC in clusters with large changes in cattle herds, as outlined above, suggests an interaction effect between both land uses. One possible explanation is that herds may be increasing with the help of more intensive management practices, curbing local effects of cattle on forest clearance. However, if such practices demand more grain as feed, then gains from intensification may be offset by an increase in demand for additional land to plant maize—if maize is sourced from local production. Similarly, shrinking cattle numbers may result in a reduction in the demand for maize, prompting the abandonment of this crop and facilitating forest transitions. This thesis is consistent with field observations and prior findings in the literature. In the Lacandona, northeastern Chiapas, ranchers are increasingly involved in buying weaned calves from Central America to sell feeder cattle to the feedlots after a short pre-fattening period. Because of this, they are using more intensive cropping practices, and maize is a key feed crop. Intensification practices also involve improvement in breeds and more emphasis on value added, which in general boost the demand of grain per animal. Similar land use practices may have been widely adopted across Mexico. Findings of de Janvry et al. (1997) and Davis (2000) indicate that increasing maize production to expand cattle herds was a widespread livelihood strategy adopted after NAFTA by small and large producers alike, meant to curb the effects of falling maize prices. Similar findings have been reported by others (García-Barrios et al. 2009; Busch and Vance 2011). Unfortunately, how different land use systems (e.g. maize and cattle ranching) interact at local scales has received little attention in the LSS literature, and little is known about how agricultural practices have changed over time in Mexico or elsewhere.

ΔCattle clusters include both confined (feedlots) and semi-intensive/extensive herds. By separating these categories and generating data partitions in P1 for each, it is possible to observe that (1) *ΔMaizeSS* is not statistically significant when I consider only confined herds (as in Figure 19b) and (2) statistical significance of this predictor within the clustered subset increases when confined herds are excluded (as in Figure 19a). One possible explanation for this is that feedlots do not depend on local sources of grain (production of maize in nearby areas), as is the case with extensive or semi-intensive operations –or even small feedlots. As I discussed in section 5.1, large feedlots buy maize from large brokers, who import the grain or source it from agro-industrial enclaves in northern Mexico or El Bajío region. Feedlot impact on maize production and LC is not local, but regional.

One may view the feedlot and the extensive/semi-intensive components of Mexican cattle herds as two independent cattle raising systems, differentiated only by technology. However, as discussed earlier in section 5.1 and 5.2, in reality, both constitute nodes within the Maize-Cattle complex. Feedlots source feeder cattle from extensive/semi-intensive ranching systems, generating large animal trade flows between Mexican and Central American biomes (as Figure 13 illustrates). This means that feedlots do not substitute extensive operations. In fact, as the Mexican case shows, demand for feeder cattle sourced from tropical regions increased, as Table 6 shows. However, for some reasons discussed earlier, source regions shifted in location and animal supply concentrated in a few regions, preeminently Central America, which by 2014 supplied half of the demand for feeder cattle in Mexico. An open question resides in knowing the leakage effects, namely how much deforestation is caused by offshore ranching in Guatemala and other Central American countries, and how many trees are saved in Mexico as a result of such trade.

6. CONCLUSIONS

The dissertation's main methodological goal was to bring commodity chain analysis to LC research. Using Mexico as a case study, the research methodology presented here aimed to address the following questions: (1) to what extent was the changing production geography of M&B the result of neoliberal reform implemented before the turn of the century? And (2) to what extent does the changing production geography of M&B explain contemporary LC patterns.? Regarding the dissertation goal, this study advances some elements that LC scientists are urged to incorporate in LC research to better understand interactions across teleconnected landscapes (Seto et al. 2012; Liu et al. 2013; Munroe et al. 2014). First, and in line with Munroe and coworkers (2014), by applying a commodity chain approach, the study moves a step forward beyond the exclusive focus on 'interactions as material flows' in the assessment of the environmental impacts of trade and globalization. The Mexican case shows that responses from increasing economic integration, in particular with the US, were not in line at all with early expectations of leading experts. The argument centers on the emergence of the maize-cattle complex as the linchpin in the reconfiguration of governance structures and geography of M&B commodity chains in a post-NAFTA era. Domestic M&B production increased after NAFTA, despite the rapid growth of corn and beef imports. Neoliberal reform created new opportunities for capital accumulation within the private sector. They lifted regulations for corporate capital, enabling the rapid expansion of large national and multinational firms. M&B commodity chains were decoupled from the governmental apparatus and re-articulated into global capital commodity circuits. Several ranchers went broke after neoliberal reform or intensified production, releasing some pressure on forested lands. Cattle herds decreased in large portions of the country and as a result, feedlots had to rely on Central American cattle. One question that remains is for how long will these trends remind. As prices for calves begin to rise, the reduction of the pressure on forest may not be permanent. Expansion of cattle ranching may begin again, taxing forested lands again.

Second, the dissertation shows how two seemingly unrelated land change processes are articulated via the maize-cattle complex: (a) FTs linked to agricultural intensification at some nodes and shrinking agricultural production at others, and (b) deforestation linked to the expansion of large corporate agents. Finally, the study moves beyond the almost exclusive attention to proximate actors within the LC literature to the analysis of interactions among heterogeneous agents whose explicit or implicit coordination determines important environmental outcomes of agro-commodity production networks, processes in which ranchers and farmers alone are often the weakest links. This is important because it opens the possibility of identifying additional loci of action to address environmental and sustainability goals.

The results are highly suggestive of the prime claims and hypotheses initially laid out. I have established that significant changes occurred in M&B commodity chains over the neoliberal reform period and had demonstrated their spatial reconfigurations. I have also shown links between the changing geography of Mexican commodity chains and shifts in Mexico's LCR, particularly for the case of beef cattle. Although intensive maize farming emerged in the wake of NAFTA, much of it remains rainfed and continues to supply peasant families. Thus, the maize production pattern has remained somewhat stable, at least in comparison with the spatial dynamics of cattle ranching. As for beef, pastures are Mexico's most extensive land use, in which case forage provision necessarily impacts native ground cover, despite the strong post-reform period emergence of fattening operations. The spatial changes of the beef component of the M&B commodity network correspond in many ways to changes in forest cover. When herds diminish, I observe FT; when herds expand, forests are lost. The econometric analysis confirms this pattern; *ceteris paribus*, adding/removing one animal unit causes the contraction/expansion of 0.3-0.4 ha of forest in Mexico. This effect varies in regions with high concentration of cattle herds, for example, where feedlots are located. Here, maize cropland expansion/contraction explains forest cover change. One shortcoming of the dissertation is that links between neoliberal reform and Mexico's changing agricultural geography were not assessed statistically, an effort awaiting future research.

As for Mexican LC, the data suggest that the nation as a whole is on the verge of reaching zero net deforestation, as deforestation rates decline overall, and increasing numbers of *municipios* show forest transition. This establishes the very real prospect of an aggregate FT in the near future. Such an outcome possesses important implications for policy interventions aimed at mitigating global warming. In this sense, a disaggregation of LC by biome suggests that FT appears most pronounced in temperate pine and dry northern forests, while deforestation has concentrated in the tropical humid areas of the south. Although Mexico's net measure of forest area may soon stabilize, the pattern of forest gain and loss across forest types suggests that biomass and biodiversity could hemorrhage even with FT, given the reconfiguration of the beef commodity chain and its increasing dependence on calves from tropical regions in Mexico and Central America. Furthermore, the consolidation of the maize-cattle complex may lead to a second ranching boom, bringing idle lands now under forest transition into production, or even reclaiming new old-growth forests for pasture. Thus, one should be cautious in concluding that neoliberal reform in Mexico has yielded a win-win in development and environment by raising incomes, sequestering carbon, and conserving a rich ecological heritage.

APPENDIX

The following form was read to, or given to read and optionally sign by, research participants.

Research Participant Information and Consent Form

You are being asked to participate in a research study. Researchers are required to provide a consent form to inform you about the research activities, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

Project title: *Linking land change and commodity chains in a globalized world: the case of Mexico*

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1. PURPOSE OF RESEARCH

You are being asked to participate in a research study that aims to understand the relationship between land use and beef-cattle industry transformations under free trade in Mexico. You have been selected as a possible participant in this study because you are a representative of ___________ (company name) with significant experience in the feedlot industry.

From this study, the researchers hope to learn how beef-cattle supply chains have evolved over the last 30 years (e.g., in terms of coordination and logistics, regulatory framework, production techniques, etc.) and how those transformations within the industry impact where and how beef-cattle are produced. In addition, we are investigating how shifts in production locations over the last 30 years have affected deforestation and afforestation patterns in Mexico.

Your participation in this study will not exceed 90 min.

2. WHAT YOU WILL DO

During the interview, you will be asked to provide information or your perspective through a set of 10 questions attached to this form. Please note that your answers will be considered "personal views," not official statements endorsed by_____________ (company name).

3. POTENTIAL BENEFITS

You will not directly benefit from your participation in this study; however, your participation may contribute to better understanding of the relationship between the evolution of the industry and the transformation of the environment.

4. POTENTIAL RISKS

There are no foreseeable risks associated with participation in this study. All information disclosed during the interview will remain confidential.

5. PRIVACY AND CONFIDENTIALITY

All conversations during the interview will be recorded, unless you request otherwise.

The data for this project will remain confidential. All information which can reveal your identity will be removed from digital recordings and transcripts, and each informant will be identified only by a randomly generated code. These files will be encrypted and stored in my personal computer and a backup in a secure remote server. Only my adviser and I will have access to the information collected. Note, however, that under very special circumstances, such as a court order, we may have to disclose information about you.

The results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous.

Please, indicate below whether you accept or decline audiotaping of the interview.

☐ Yes, I agree to allow audiotaping ☐ No, please do not audiotape

Initials____________

6. YOUR RIGHTS TO PARTICIPATE, SAY NO, OR WITHDRAW

Participation is voluntary. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

You have the right to say no.

You may change your mind at any time and withdraw.

You may choose not to answer specific questions or to stop participating at any time.

7. COSTS AND COMPENSATION FOR BEING IN THE STUDY

You will not receive money or any other form of compensation for participating in this study.

11. CONTACT INFORMATION

If you have concerns or questions about this study, such as scientific issues, how any part of it is done, or to report injury, please do not hesitate to contact me (Phone: US 517 802 8494, email:).

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, MSU, East Lansing, MI 48824.

12. DOCUMENTATION OF INFORMED CONSENT.

Your signature below means that you voluntarily agree to participate in this research study.

_________________________________ _____________________________

Signature Date

You will be given a copy of this form to keep.

Organization level interview questions

Segment: ___________________

Date: _____________

Organization information

Organization: _____________________

No. Members: _____________________

Founding year: ____________________

Perceived changes within the industry§ after NAFTA

1. From your perspective, what are the main changes within the * _________ industry since the enactment of free trade policies in the 1990s? (new technologies and input access, logistics, learning and human capital, markets and marketing, etc.)
2. In what ways have free trade policies been beneficial for the industry? In what ways have they been harmful? Which sectors/producers within the industry have benefited and which ones have suffered the most with free trade policies.
3. How has the role of the organization changed in response to free trade policies? If the organization was founded after the 1990s, in what ways does the organization respond to or is consistent with the new economic environment?

Access to markets

4. Which are the most important markets/customers (supermarkets, feedlots, milling industry, food processing industry, etc.)?
5. What are the most important factors that allow access to those markets?
6. Are all members equally successful in those markets? Which members are the most successful, which ones have more problems? Does the location of the members determine how successful they are?
7. What type of support does the organization provide to facilitate access of members to those markets?

Governmental support

8. What is the most important governmental support policy/program within the industry?
9. Do all producers have equal access to governmental support? Which ones are most successful, which ones have most problems?
10. What type of support is provided by the organization to facilitate access to governmental support?

Regulations

11. Which are the most important regulations for the industry and who implements them? (e.g. quality standards)

12. Do/can all producers comply with the regulations? Which ones are most successful, which ones have the most problems?
13. What type of support is provided by the organization to suppliers to comply with such regulations?

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* Beef-cattle/Maize

Firm level interviews (feedlots)

Feedlots Date: ____________

Company information

Business name: ______________________________

Business type:
(e.g. partnership, family own, corporation) ______________________________

Locations(s): ______________________________

Sales (three-year avg.): ______________________________

Started operations on: ______________________________

Input suppliers

1) A) Please list the name, location, and feed type of three of your most important feed suppliers in order of importance. (compare corn versus sorghum).

Supplier	Location (e.g. *municipio*)	Feed type
____________	____________	____________
____________	____________	____________
____________	____________	____________

B) Please explain. Since you started operations, what are the main changes you perceive in terms of feed availability and feed supplies? Has the availability and quality of feed improved? What types of suppliers are more important today than in the past?

2) A) Please list the name and location of three of your most important cattle suppliers in order of importance.

Supplier	Location (e.g. *municipio*)
____________	____________
____________	____________
____________	____________

B) Please explain. Since you started operations, what are the main changes you perceive in terms of cattle availability and cattle supplies? Has the availability and quality of cattle improved? What types of suppliers are more important today than in the past?

3) A) When you buy cattle, which criteria do you consider when choosing your suppliers? Please check all items that apply and explain why each is important to you.

a) Price ☐ ________________________________

b) Quantity they can sell ☐ ________________________________

c) Place of production ☐ ________________________________

d) Product quality provided:

Weight ☐ ________________________________

Breed ☐ ________________________________

Age ☐ ________________________________

Health ☐ ________________________________

Other __________ ☐ ________________________________

e) Other _____________ ☐ ________________________________

B) From the list above, which is the most important criterion that guides your choice of suppliers?

Customers

4) List your main products (e.g. calves, stockers, finished animals) and rank by revenue.

5) A) List 3 of your top customers (in terms of revenues), percentage of sales that goes to each buyer, product sold, and type of business.

Customer	**Sales**[1]	**Product sold**	**Business type**[2]
________________	_________________	_________________	_________________
________________	_________________	_________________	_________________
________________	_________________	_________________	_________________

[1]Percentage of total sales (3 yr average). If possible, complement this information with statistics from balance sheets

[2]Partnership, family-owned, corporation/small, medium, large firm

B) Please explain. Since you started operations, how have your customers changed? Which customers are more important today? Which customers are no longer important for you today?

6) A) Which of the following criteria do you consider are most important for your customers? Please check all that apply and explain why it is important.

- **a)** Price ☐ ________________________________
- **b)** Quantity I can sell ☐ ________________________________
- **c)** Place of production ☐ ________________________________
- **d)** Product quality provided:
  - Weight ☐ ________________________________
  - Breed ☐ ________________________________
  - Age ☐ ________________________________
  - Health ☐ ________________________________
  - Other __________ ☐ ________________________________
- **e)** Other _____________ ☐ ________________________________

B) From the list above, which is the single most important criterion that allows you to sell your products?

Innovations and changes in internal organization

7) Since you started operations, which have been the most important changes within the business in terms of:

- **a)** New technologies (including animal health, genetics, infrastructure).
- **b)** Transportation
- **c)** Contracts with customers and suppliers
- **d)** Education (e.g. workers school years)
- **e)** Marketing
- **f)** Other

Policies/regulations

8) A) Do you participate in any of the following governmental programs? Check all that apply

- **a)** PROGAN ☐
- **b)** Reconversión Productiva ☐
- **c)** Diesel agropecuario ☐
- **d)** Trópico Húmedo/Seco ☐
- **e)** Ganadero ☐

f) PROVAR ☐

g) PYME ☐

h) ... *list others*

9) Rank the following elements from 1 to 10 in terms of positive impacts for your business. 10 for greatest impact, 1 for no impact. Please, discuss why it has been positive or why it has not been positive.

a) Access to export markets ______

b) Access to maize imports ______

c) Access to infrastructure ______

d) Animal health services ______

e) ... *list others* ______

Membership Organizations

10) In which of the following organization are you a member? Please, rank them in terms of importance for your business (10 most important, 1 least important).

a) Local/Regional cattle men association ☐ ____

b) CNG ☐ ____

c) AMEG ☐ ____

d) ANETIF ☐ ____

e) Padrón de Ganaderos ☐ ____

f) ... *list others* ☐ ____

Firm level interviews (grain brokers)

Date: ______________

Company information

Business name:	
Business type: (e.g. partnership, family-owned, corporation)	
Locations(s):	
Sales (three-year avg.):	
Started operations on:	

Input suppliers

1) Please name the three most important *municipios* for you for buying maize. List from most to least important.

a) ________________

b) ________________

c) ________________

2) Since you started operations, have you bought maize from the same *municipios*/regions? Have other places become more important today? Have other *municipios*/regions become less important?

3) A) Which criteria do you use to choose where to buy maize grain? Check all items that apply and explain why each is important to you.

d) Price I can get ☐ _________________________

e) Volume of grain I can buy ☐ _________________________

f) Grain quality:

(1) Grade[14] ☐ _________________________

(2) Moisture content ☐ _________________________

(3) Size & homogeneity ☐ _________________________

[14] Mexican Norm defines 4 grades: MX1,MX2,MX3, and MX4

g) Other ☐ ______________________

B) From the list above, which is the single most important criterion you use to choose your maize suppliers?

Customers

4) What are your main products? (whole grain, ???). Rank by revenue.

5) A) List your top 3 customers (in terms of volume sold and revenues), the percentage that goes to each buyer, product sold, and type of business.

Customer	**Sales**[1]	**Product sold**	**Business type**[2]
________________	________________	________________	________________
________________	________________	________________	________________
________________	________________	________________	________________

[1]Percentage of total sales (three-year average). If possible, complement this information with statistics from balance sheets

[2]Partnership, family-owned, corporation/small, medium, or large firm

B) Please explain. Since you started operations, how have your customers changed? Which customers are more important today? Which customers are no longer important for you today?

6) To sell your products, which criteria are important for your customers? Check all that apply and explain why each is important.

a) Price bargain ☐ ______________________________

b) Quantity I can sell ☐ ______________________________

c) Place of production ☐ ______________________________

d) Product quality ☐ ______________________________

e) Other ____________ ☐ ______________________________

Innovations and changes in internal organization

7) Since you started operations, which have been the most important improvements in terms of:

a) New technologies (including animal health, genetics, infrastructure).

b) Transportation

c) Contracts

d) Education (e.g. workers school years)

e) Marketing

f) Other

8) Do you participate in any of the following governmental programs?

a) Apoyos a la Modernización de Infraestructura ☐

b) Others _____________ ☐

Membership Organizations

9) In which of the following organization are you a member? Please, rank them in terms of importance for your business (10 most important, 1 least important).

a) ANEC ☐____

b) COMAGRO ☐____

c) Others ____________☐____

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