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Where Deforestation Leads to Urbanization: How Resource Extraction is Leading to Urban Growth in the Brazilian Amazon

Dr. Peter Richards and

Institute at Brown for Environment and Society, Population Studies and Training Center, Brown University, Phone: 401-863-5869 (office), Phone: 401-692-2881 (cell), Fax 401-863-3839

Dr. Leah VanWey

Department of Sociology, Institute at Brown for Environment and Society, Population Studies and Training Center, Brown University, Phone: 401-863-3184 (office), Fax 401-863-3839

Peter Richards: peter_richards@brown.edu; Leah VanWey: Leah_Vanwey@brown.edu

Abstract

Developing the Amazon into a major provider of internationally traded mineral and food commodities has dramatically transformed broad expanses of tropical forests to farm and pasturelands, and to mining sites. The environmental impacts of this transformation, as well as the drivers underlying the process, have already been well documented. In this article we turn our analytical lenses to another, less examined effect of Amazon land use and environmental change, namely the creation and development of new urban areas. Here we argue that urban growth in the Amazon is a direct residual of international interest in the production of traded commodities, and of the capacity of local urban residents to capture capital and value before it is extracted from the region. Specifically, we suggest that urban growth is occurring fastest where cities have access to both rural export commodities and export corridors. We also show correlations between urban growth and lower rural population density, and cities' capacities to draw migrants from beyond their immediate rural surroundings. More broadly, we argue that urbanization in the Amazon is better interpreted as a symptom rather than a driver of the region's land use and land cover change.

Keywords

Brazilian Amazon; Urban Growth; Development

Introduction

With each harvest and each tropical Amazon dry season the raw materials and primary goods of the rainforest and the cerrado, or of the land upon which now-felled forests once stood, are poured from silo to truck bed and hauled south in a sputtering rust-hued cloud of diesel exhaust toward Brazil's coastal metropolises and Atlantic ports. Near the start of their journey, often near-to or at the point where access roads transect arteries of asphalt, raw

Correspondence to: Peter Richards, peter_richards@brown.edu.

resources will pass through one of the Amazon's variously chaotic interior cities. In many cities the fruits of the land will merely flow past in a continuous stream of grain- and lumber-loaded lorries. In others, resources are stored, lightly processed, butchered and frozen, or prepared for longer journeys, whether to the nation's coastal centers of consumption, or abroad, to the distant ports of Asia or Europe. In this article we focus not on the commodities of the Amazon, *per se*, nor on the land from which they are reaped. Rather, we turn our attention to the interior cities through which these commodities pass, and which we argue, these commodities have *created*.

In this research we seek to re-evaluate the drivers of urbanization in the Amazon. In doing so, we acknowledge that in previous decades environmental change in the Amazon was wrought by government actions, and by the pushing of both people and capital into the basin (Godfrey and Browder 1996, Browder and Godfrey 1997). Cities, during this previous period, acted as nerve centers of environmental change, and as base points for the administration of rural colonization and development projects. However, since the 1990s we argue that the role of urban centers as drivers and enablers of rural environmental change, and their relationship to rural surroundings, has rapidly changed. Today, capital investments come to the Amazon via trade connections and global telecouplings, and are brought in exchange for the region's rich reserves of minerals and the fruits of its agricultural lands. And more so than ever before, the benefits of these investments are staying, in the form of economic growth, rising socioeconomic indictors and public investments. They are also dramatically remaking the region's cities.

We illustrate this remaking with cities such as Sinop, Sorriso, and Lucas do Rio Verde in northern Mato Grosso, each of which has emerged from the midst of Mato Grosso's densely planted soybean regions, and each of which oversees the cultivation of soybeans destined for distant consumers. And we place the substantial growth of Parauapebas in Pará in the context of the iron ore complex at Carajás, from where iron deposits are shipped over oceans to feed global demand for modern housing materials. Further, we link urban growth in Altamira and in Tucuruí, or in western Rondônia, to the massive hydroelectric projects on the Xingu and Araguaia that power Brazil's growing industrial base and its interest in aluminum smelting. And we argue that expanding cattle herds, newly opened to global consumers and the important national markets in Brazil's southeast by measures to control *aftosa*, are driving urban growth in central and southern Pará State.

The common threads that bind the rapidly growing cities of the Amazon are their proximity and access to the rich resource fields of the basin, and their ability to capture these resources and ship them to distant points of consumption. This leads to our principal argument, namely that the Amazon's future cities will be framed by the light processing of global commodities, and by their sustainable access to natural resources, whether in terms of land for pasture or row crops, iron ore, or the most powerful freshwater hydrologic system on the planet. The future cities of the rainforest, we argue, will no longer be dependent on government subsidies and bureaucratic largesse, but rather will reflect landscape changes, international commodities markets and rates of exchange. Further, they are and will be inextricably tied to consumption choices and behaviors in São Paulo, or even in cities in Asia, Europe, or the Middle East.

We proceed first with a brief summary of recent research on the linkages between rural regions and urban centers. We then consider the prevailing literature on urbanization in the Brazilian Amazon. Here we pay particular attention to the theoretical framework that has dominated discussions on the drivers of urbanization in the region over the past decades, Browder and Godfrey's *disarticulated urbanization* thesis. We then advance to our analytical work, which focuses on the rural economic and demographic contexts in which the Amazon's cities are growing. While we present evidence to link urban growth to rural resources, we refrain from attempting to divine or estimate causal impacts on urban growth. Rather, we draw attention to correlations and patterns, we situate growth in the context of rural economic changes, and we update a guiding framework from which to understand and evaluate the new urban frontiers of Brazilian Amazônia and their role as a component in the region's landscape change during the past decade. In this regard, we connect our work to recent interests in distal spatial linkages, and in discussions of the broader social impacts of landscape change (Lambin and Liu 2014).

The Rural-Urban Relationship

Socioeconomic research on urban growth, and the relationship between urbanization and rural economic changes, includes research on both the economic advantages of decreased transaction costs and agglomeration economies in urban areas (Tobler 1970, Pred 1973, Black and Henderson 1999), and on the draw of urban wages and amenities to a rural labor supply (Lewis 1954, Sjaastad 1962, Todaro 1980, Bryceson 1996). Much of this latter work has implicitly subscribed to a conceptual framework where rural regions provide natural resources and food to local urban residents, while urban centers supply, in return, manufactured goods and services (von Thünen 1966, Cronon 1991).

At the national or regional scale, research has linked urban growth to regional scale changes in forest cover both positively, through forest transition theories (Walker 1987, Rudel, Bates and Machinguiashi 2002, Grau et al. 2003, Walker 2012) and negatively, through changing behaviors and consumption patterns (DeFries et al. 2010). Broadly, much of this literature has viewed rural landscape changes as an artifact or response to shifting behaviors and demographics in urban areas. Urban growth in developing nations, per this prevailing story, leads directly to new deforestation, and by consequence, losses in biodiversity and new carbon emissions (Seto, Güneralp and Hutyra 2012). In this research we fully acknowledge this scenario, but recognize that under certain scenarios cities may be best regarded as *symptoms* rather than drivers of forest loss and environmental change.

In this article we shift our analytical lens away from examining rural land use and economic changes as a function of local or regional urban growth. Instead, we turn to consider growth in urban areas as a function of changing rural dynamics. In this regard, we recognize that global interests in natural resource commodities have reshaped rural landscapes in lesser developed nations across the planet, often to devastating environmental effect. However, we argue that basic commodities and raw materials are not only reshaping landscapes, but are making and remaking cities. Here, we argue the urban-rural relationship rests not on the spatial or sector transfer of labor, or in the production of manufactured goods, but rather on

the capacity of urban areas to absorb, circulate, and consume the capital generated from their surroundings.

Our approach to understanding urbanization is particularly relevant in the Brazilian Amazon, where resources have played a key role in driving the last decade of economic growth. Yet this process is hardly endemic to Brazil. In fact, work elsewhere has recognized a trend of urbanization in the absence of industrialization or a manufacturing sector (Gollin, Jedwab and Vollrath 2014). Urbanization without industrialization occurs through the consumption of resource rents, or where the services and support sectors to the extractive or agricultural sectors are sufficient to support urban growth. In this respect, cities spanning regions as varied as Qatar, Venezuela, and even western North Dakota are growing rapidly, but doing so without, or in spite of, a local industrial or manufacturing sector. Even across the United States, many of the fastest growing metro areas and micropolitian (with populations between 10,000 and 49,999 individuals) centers are closely tied to the extraction of petro carbons. Surrounding rural regions, in these scenarios, relate to local urban centers as suppliers of capital and resources, rather than of labor resources or food goods. The sustainability of urban growth in these cities will depend on both the continuation of favorable economic climates for exports, and on the ability of urban areas to capture and re-circulate resource rents, and to redirect capital investments into public infrastructure and, potentially, urban manufacturing.

Our perspective on urbanization departs in several respects from the prevailing framework for conceptualizing urban growth in the Amazon. We therefore argue that understanding urban growth in the Brazilian Amazon requires a refitting of our understanding of the linkages between urban growth and rural environmental change, and specifically, a re-conceptualization of the region's urban growth as a symptom rather than a driver of landscape change. In the next section we begin this process by turning to earlier research on urbanization in the Amazon.

Urbanization in the Brazilian Amazon

Urbanization in the Amazon can be described as occurring in three phases: (1) the rubber period of the turn of the 20th century, in which cities served as catchment points for latex flowing downstream to international markets, and as supply points for labor and material resources moving upstream in support of extractive activities in the inner reaches of the basin (Weinstein 1983, Barham and Coomes 1996, Hecht 2013); (2) the public colonization projects of the 1970s and 1980s, when Brazil's ruling generals, under the premise that occupying the region was of key national, if not economic importance, hurled a succession of colonization and occupation projects at the Amazon (Becker 2005); and finally, (3) the globalization turn of the last two decades, and the emergence of commodity producing cities such as Lucas do Rio Verde and Primavera do Leste, in Mato Grosso. Much of the literature on urbanization in the Amazon, and on the impacts of urban growth in the rainforest, has focused on the colonization period, when urban areas served as administrative centers and hubs of bureaucracy, and serviced the chainsaws, tractors, and laborers that stood over the newly cleared forests (Godfrey 1990). Of this work, perhaps the most notable outcome is

Browder and Godfrey's influential volume on urbanization in the Amazon, *Rainforest Cities* (1997).

In *Rainforest Cities*, Browder and Godfrey conceptualized the geopolitical occupation of the Amazon through the lens of *disarticulated urbanization*, a framework they developed and employed to explain the plurality of spatial, institutional, and historical forces that underlie the urban development of the Amazon. Urban growth in the Amazon was neither reliant on the movement of local rural labor to urban centers, nor on the production of rural capital (for example through agriculture). Rather, urban growth was tied directly to the largesse or prescriptions of state or federal governments. Government development programs, rather than the organic economic potential of their surroundings or their citizens, they argued, were keeping the cities of the Amazon economically sustainable and maintaining its populations. Fundamentally, per this conceptualization, urbanization in the Amazon was the economically irrational, environmentally destructive legacy of the military government's designs for the region.

Many of the foundational components to Browder and Godfrey's disarticulated urbanization thesis continue to shape urbanization in the Amazon. Most notably, the disassociation between urban growth and industrialization persists in the present century, as does the asymmetry in regional settlement and development structures, and the general heterogeneity of the region's social spaces (Browder and Godfrey 1997, p11). Similarly, the dichotomies between the rural and urban in the Amazon are blurred, in part because rural land owners are often based in urban areas (Browder and Godfrey 1997, p12). We also recognize that the dependence of the region on external demand for food commodities likewise continues to shape rural production strategies across the Amazon (Browder and Godfrey 1997, p13). We argue, however, that the past twenty years of development and the globalization of the region have challenged a number of the key concepts of the disarticulated urbanization thesis. First, we argue that agriculture now plays a key role in driving urban growth in the Amazon, particularly as a means for drawing in international capital and investments. We also argue that investments in agriculture are translating to sustainable extraction of capital, and that this capital is increasingly being captured locally and contributing to urban growth. Second, we argue that resources of the Amazon, including its beef and grain production, are now traded globally, and are no longer encumbered by trade restrictions or production incentives favoring crops for domestic consumption. Third, while we acknowledge that state level development patterns vary across Brazil and continue to shape investment decisions, a nation-scale emphasis on expanding natural resource exports constitutes a common thread to the region's recent development, and sheds light on why certain cities have grown faster than others. These latter developments trace directly to the Amazon's recent transformation from a geopolitical objective and regional supplier of domestic resources to a global supplier of basic food and resource commodities.

The transformation of the Amazon, and of Brazil more broadly, into an international bread basket and source area for mineral commodities has been widely linked to market liberalization policies (Helfand and Rezende 2004), and to a progression of structural changes favoring export producers (Nepstad, Stickler and Almeida 2006, Walker et al. 2008). Falling transportation costs to the Amazon, combined with record high prices in

Brazil for traded commodities such as soybeans (in 2002, 2004 & 2012), beef (2004, 2008, & 2010), aluminum (2005, 2008) and iron (2010, 2011), and market reforms have sequentially rendered the Amazon, perhaps once a welfare destination for subsidized government projects and loans, into not only a hotspot for environmental change but one of Brazil's greatest drivers of economic growth (Figure 1).

We argue that the globalization of the basin's resources has brought about a shift in the utility of urban areas in the Amazon, namely from merely administering space (as during the era of military governorship), to extracting capital and value, and facilitating the movement of prized resources and products to external consumers. In a process that echoes the boom and bust cycle of past urbanization periods, we argue that urban growth is once again concentrated in those cities that are best positioned to both extract capital from the region's resources, those that can provide institutional support and lifestyle amenities, and those that are capable of facilitating the movement of raw or lightly processed commodities to export. However, a principal difference between the present day commodity boom and the boom and bust cycles of time past resides in the relative spatial concentration of extractable value and capital investments in the region, as well as the complexity and magnitude of the support sectors to the extractive and production processes. Thus whereas factor scarcity and mobility once inhibited investments during the rubber era (Barham and Coomes 1996), today the relative permanence and clustering of agricultural production (Garrett, Lambin and Naylor 2013b), or of the scale of the mining sector, combined with the maturation of a generation of colonists, now validates longer term community investments. Our intention in this article is thus not to refute the disarticulated urbanization theory of Browder and Godfrey, which was first articulated in the early 1990s, but to suggest rather that as new political and economic pressures come to shape the region, the dynamics of urbanization here have evolved.

Capitals and Categories

In many respects, the map of the Amazon's cities is a distributional record of attempts to colonize and control the region, a timeline that extends from pre-Colombian Amerindian settlements, to 17th century Jesuit missions and late 19th century rubber collection points and telegraph posts (which includes many of the Amazon States' present-day capitals), to mid-20th century colonization plans under Brazil's military dictatorship, and to the 21st century commodity boom. The oldest cities are located on the main channel of the Amazon; others on its principal tributaries. The relatively newer cities adorn the road projects that are the legacies of infrastructure initiatives from the 1970s. Many of the earliest cities of the Amazon have grown into state capitals and are presently home to legions of relatively well-paid bureaucrats and public employees. These cities remain the largest in each of their respective states, and have a distinctive character due to their role as centers of government and commerce.

In this research we focus on a set of Amazon *mid-size cities*, or those non-capital cities with a population of more than 40,000. We exclude cities in Maranhão and Tocantins, two states that are nearly entirely composed of cerrado vegetation, and which differ tremendously in terms of settlement patterns and demographics from the rest of the Legal Amazon[i] (see

Figure 2) and all capital or capital metro area cities. [ii] We thus focus on thirty-six cities across Mato Grosso (9), Pará (16), Acre (1), Rondônia (5), and Amazonas (5). A list of these cities is included in the appendix as Table A-1. Nineteen of these cities have grown at rates of more than thirty percent between the 2000 and 2010 censuses; ; seventeen have grown at slower rates (IBGE 2000, IBGE 2010). We define the faster growing cities as *high-growth* cities, and the remainder as *low-growth* cities.

Natural Resources and Rural Context

Our analysis starts with a stylized division of the Amazon's cities by region and rural resources. We begin in Mato Grosso, where we connect urban growth to the rise of the state's agricultural sector. We then consider cities in a corridor of central and southern Pará, where urban growth has occurred within the context of expanding mineral resource extraction, hydroelectric projects, and cattle production. Finally, we turn to the less accessible cities of the western Amazon states.

Mato Grosso

Agricultural growth and pasture expansion in Mato Grosso have been widely recognized as drivers of forest loss in the Amazon and cerrado forests (Hecht 1984, Walker, Moran and Anselin 2000, Browder et al. 2008, Walker et al. 2009a). Much of the state's agricultural growth occurred between 2000 and 2005, when a weakened and devalued real heightened returns to globally-traded commodities (Richards et al. 2012). This period, at times referred to as Brazil's soybean boom, has been widely studied and publicized, both in academic publications and in popular media, particularly as soybean growth was identified as a direct driver of forest loss in the region (Morton et al. 2006, Hecht and Mann 2008). Far less understood, however, is how environmental change in Mato Grosso has influenced socioeconomic change in the region.

Of the nine non-capital cities in Mato Grosso over 40,000, six are located in proximity to densely planted agricultural areas (see Figures 3 and 4). Sinop, Sorriso, and Lucas do Rio Verde, in northern Mato Grosso, are all central to the region's soybean sector. Elsewhere, Primavera do Leste and Rondonopolis, in the east, and Tangará da Serra, in the west, are key urban centers to the production and transportation of the state's agricultural harvests. Each of these six cities is surrounded by soybean production (see Figure 4). Each has also has grown by more than thirty percent over the past decade; and with the exception of Rondonópolis, a much larger city at approximately 200,000, each has doubled in population since 2000. The correlation between soybean production and urban growth in Mato Grosso's cities is quickly brought into sharp contrast by comparing soybean producing cities to their non-soybean producing peers. Mato Grosso's three non-soybean producing cities: Alta Floresta, Barra do Garças, and Cacerés, have remained largely stable in terms of population

[i]The Legal Amazon region includes the seven states of the north region (Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, and Tocantins) plus Mato Grosso and most of Maranhão State. The region covers 59% of Brazil's territory, including all of the Amazon biome (in Brazil).

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and economic growth, and exhibited some of the lowest growth rates not only in Mato Grosso, but for mid-size cities across the Legal Amazon.

How does agriculture drive urban growth? First, relative to other land uses in the Amazon region, agriculture demands a relatively high supply of wage labor and capital inputs. Labor, both skilled and unskilled, is not only employed directly in planting, harvesting, and other on-farm activities, but also engaged in providing complementary services ranging from financing and regulation to transportation and silage. Second, the wealth reaped from the land through paid labor, the circulation of agricultural inputs, or the buying and selling of harvests, supports a regional-level service economy. Third, soybean farming regions retain a larger portion of farm managers or manager-owners living locally (as opposed to other urban areas), and living in the local urban area (as opposed to living on the farm) than do non-soybean cities. Landowners in areas surrounding the set of soybean cities are more likely to live local either in the county seat or on the farm) than landowners in non-agricultural cities (IBGE 2006). Not only does the presence of landowners within the local city ensure that a larger proportion of rural resources are circulated locally, but that these regions will develop a strong core of social infrastructure, from schools to cooperative institutions, as recent research has demonstrated (Garrett, Lambin and Naylor 2013a, VanWey et al. 2013, Weinhold, Killick and Reis 2013). Indeed, in terms of HDI, many of the Amazon's highest ranking cities are those that are closely tied to the agricultural sector (PNUD 2013).

Pará

Pará, in many respects, gave rise to the concept of the boom and bust in frontier urbanization in the Amazon, with ethnographic and political economic work detailing the urban growth and subsequent stagnation that accompanied new roads and access to the region, and the rush to claim land, or to extract and deplete local timber or gold (Cleary 1990, Godfrey and Browder 1990, Schmink and Wood 1992, Roberts 1995). Today, the south of Pará, and those areas in central Pará that lie outside of the region's mosaic of protected areas, are among the most heavily deforested areas in the Amazon. Deforestation, public protests over land rights, land invasions, and other forms of frontier conflict also layer this area with levels of violence (Aldrich et al. 2011, Walker et al. 2011). The state is also home to many of the Amazon's fastest growing cities (Figure 5a).

Urban growth in Pará is supported by (1) minerals (iron and bauxite), (2) hydroelectric power, and (3) beef (see Figure 5b). Two cities in Pará are closely connected to mineral rents. Parauapebas, the fastest growing city in the Amazon region is closely linked to the Carajás complex (Roberts 1992), while Oriximiná includes multiple bauxite mines.

In Paragominas, urban population growth has been rapid since the 1980s. However, the growth rate has accelerated since 2000. From 1991 to 2000 Parauapebas grew at approximately four percent per year. However, since the millennium this rate has increased to approximately eleven percent per year, making it one of the fastest growing cities in Brazil. Not coincidentally, iron ore prices, which stagnated at less than 15$US per metric ton from the 1980s through to the early 2000s, increased to historic highs in the late 2000s, cresting at nearly 200$US per ton in 2010. Oriximiná is more closely connected to Bauxite production. Brazil is the world's third largest bauxite producer, a position achieved, in part,

on the strength of its Amazon deposits, and both Alcoa and Mineração Rio do Norte operate large bauxite mines in the vicinity of Oriximiná. While neither mine approaches the magnitude of the Carajás complex in terms of reserves or invested capital, both involved enormous investments, and supply resource rents to Oriximiná.

Hydropower is also a key driver of economic and urban growth in Pará. The rapid growth of the cities of Altamira and Tucuruí, for example, correspond to mega-investments in hydroelectric facilities. The 8,000MW Tucuruí facility on the Tocantins River is among the largest in the country (Browder 1997, Fearnside 2001); meanwhile, even larger facilities are under construction on the Xingu River, near the city of Altamira (Stickler et al. 2013). The cities of Tucuruí (pop 92k) and Altamira (84k) both rank among the fastest growing urban areas in Pará, adding more than thirty and twenty thousand in population over the past decade.

Ranching is also expanding across Pará and is occurring in the midst of several of the region's fastest growing cities. Ranching is hardly new to the Amazon, and indeed, legions of research have examined the expansion and profitability of ranching in the basin's uplands, particularly in regard to how cattle have reshaped the Amazon landscape (Malingreau and Tucker 1990, Faminow 1998, Walker et al. 2000). However, over the past decade the Amazon's cattle sector has been transformed into a global beef supplier by the control of foot and mouth disease (Kaimowitz et al. 2004, Nepstad et al. 2006, Walker et al. 2009b). Perhaps there is nowhere where the impacts were clearer than in Pará. From 2000 to 2010 ranchers in south and central Pará expanded their herds by nearly six million animals. The São Felix (micro) region (see Figure 5a and 5b), as well as Tucuruí and Altamira, each registered gains of more than 1.5 million animals. Likewise Parauapebas and Marabá expanded by more than 0.5 million animals (IBGE 2013).

The cattle cities of eastern Pará have grown rapidly with the region's cattle herds. São Felix, in the space of the last decade, grew from 8,000 to 45,000 people. Marabá added more than 50,000; Tucuruí and Tailândia each grew by more than 30,000, or by more than thirty percent over the past decade. The sustainability of the cattle sector, as with the agricultural cities of Mato Grosso, and the mineral-rich cities of Pará, will depend on continued access to global cattle markets and on volatile beef prices. However, the south of Pará is rich in three primary resources to the beef sector: the precipitation, extensive, affordable land suitable for pasture, and a tropical climate favorable to Nellore cattle.

The mechanized agriculture sector, which has had a key role in driving urban growth in Mato Grosso, has had a lesser impact in Pará. In Pará, soybeans are prominently planted in the vicinity of the rapidly growing city of Paragominas, a commercial center for the soybean sector in the northeast of the State, and Santarém, home to a deep-water soybean port operated by Cargill and a limited agricultural district.

Western Amazon: Acre, Amazonas, and Rondônia

We close by shifting our focus to the western Amazon States of Acre, Rondônia, and Amazonas. Only three cities here have grown at faster than thirty percent over the past decade: Vilhena and Ariquemes, in Rondônia, and Cruzeuiro do Sul, in Acre (Figure 6).

Vilhena, which borders Mato Grosso, is the center for the soybean sector that dominates agricultural production in eastern Rondônia, and urban growth here closely parallels growth in cities in Mato Grosso such as Paragominas or Sinop. From 2000–2010 population in Vilhena grew from 55,000 to 72,000. Ariquemes, in northwest Rondônia, was settled more recently and is still under the process of colonization. The timber sector continues to occupy a major role in the city's economy, while the *garimpo bom futuro*, perhaps the largest complex of open air gold site in the world, lies less than fifty kilometers west of the city. The city has grown by more than 20,000 over the past decade, or nearly 40 percent.

The only other city that grew at more than thirty percent over the last decade is Cruzeiro do Sul, a former rubber town on the Jurua River, near the western border with Peru. Cruzeiro do Sul is the planned recipient of substantial investment in infrastructure, comparable to the investment in dam construction elsewhere. It is the eastern terminus of highway and railway construction from Peru, under the aegis of Initiative for the Integration of the Regional Infrastructure of South America (IIRSA) integration and development hubs. The city has grown to more than 55,000, an increase of more than forty percent in the past decade, and double from its population in 1990.

People and Socioeconomic Context

The past section, which considered geographic access to natural resources and their relation to urban growth, omitted a critical discussion of another rural resource, namely the distribution of rural labor and population. Here we consider rural socioeconomic situations, the source locations of in-migrants to the Amazon's interior cities, and migrant's backgrounds.

Population Density

We begin by examining data from Brazil's rural census tracts (called census sectors). Sector-level data allow for a far larger pool of observations (n=~16,000 rural sectors across the nine states of the Legal Amazon) than municipal-scale data (n=771). They also allow for the separation of rural from urban sectors, an attribute that is critical to the goals of this analysis, namely to consider the urban as a function of the rural, and thus the differentiation between rural and urban characteristics. While the refined spatial scale of the sector level data provides greater accuracy and accounts for the sometimes immense internal heterogeneity in economic, environmental, and social characteristics of county level census data, the dataset contains a relatively limited base of information. In this section we thus focus on only three principal points of analysis: (1) population density; (2) percent of rural population making minimum wage; and (3) average rural household income.

To examine the variation in socioeconomic conditions surrounding each of our thirty-six mid-sized cities we calculated (a) buffers around each city center, in one kilometer intervals for up to 50km (average levels remain stable over 50km); and (b), the geographic mean, or centroid location, or each rural sector from the census data. We then estimate the average population density as a function of area and the total population and income captured in each buffer.

Our results reveal several commonalities across high-growth and low-growth cities, as well as differences between states. First, faster-growing urban areas are surrounded by less populated rural areas. In Pará State population density in rural areas around slower-growing cities was roughly twice that of the faster-growing counterparts. Population density in rural areas around all cities in Mato Grosso was very low, at approximately one person per square kilometer. Next we find that average rural incomes are higher in rural areas surrounding faster-growing cities. Indeed, average monthly household incomes around high-growth cities in Mato Grosso averaged more than 1500$Rs/month (about 1000$US in 2010), or several hundred $Rs more than around slower growing cities. Average household incomes are highest in rural areas in the vicinity of Sorriso and Lucas do Rio Verde, two cities dominated by broad acre agricultural systems.

County- and state-level census data are congruent with these findings. In 2010, for example, Mato Grosso boasted one of the smallest differentials in monthly per household output between rural and urban regions, even as per-household urban output ranked highest in the Amazon. This trend is clearest in the individual counties at the heart of Mato Grosso's soybean areas with Sorriso, closely followed by Lucas do Rio Verde, boasting a per capita income for working men ranking among the highest in rural Mato Grosso (IBGE 2010). These statistics suggest that the fastest growing urban areas are surrounded by relatively profitable, but sparsely populated rural areas. This is in quiet contrast to the declining marginal utility of labor in the traditional theoretical models of rural out-migration (e.g. Lewis 1954). It is also in contrast to models suggesting that urban areas grow, in part, by absorbing excess labor from the surrounding countryside. We argue, rather, that the negative correlation between rural populations and urban growth may stem from urban access to resources. An underlying premise of this article, and of Browder and Godfrey's disarticulated urbanization thesis, is the appropriation of rural resources to support urban lifestyles and the consumption of imported manufactured goods. Here we extend this by arguing that densely populated rural areas will not only absorb a greater percentage of rural resources before resource rents can be transferred to and consumed in urban areas, but may also inhibit the production of resource commodities that benefit from returns to scale. Consequently, urban access to rural resources is enhanced in rural areas with fewer, but wealthier rural residents.

New Residents

Past research on urban networks has highlighted the regional linkages that connect urban areas. Godfrey (1990), for example, suggested that frontier cities serve as communication hubs, while recent work by da Costa and Brondizio recognized the importance of interurban linkages as an influence underlying the location and extent of urban growth (da Costa and Brondízio 2009). Here we consider source locations of in-migrants to mid-sized cities through sample data, equivalent to the US long-form questionnaire, from Brazil's 2010 census. We compiled the sample data for urban areas in each of the principal interior cities of the Amazon and linked the data to spatial information on migration origins in a GIS. The results shed light on the prior location of recent in-migrants to the Amazon's cities and, by proxy, the source locations for the labor and population bases that underlie the formation of the Amazon's new urban areas.

The sample data suggests that many of the in-migrants to the fastest-growing cities are arriving not from the immediate surroundings of these cities, but from farther distances. Those cities that draw the smallest percentage of new residents from inside their county (less than 16%), namely Sorriso, Paragominas, Parauapebas, and Lucas do Rio Verde, are also among the fastest growing in the region. Conversely, many of the slowest growing cities are relatively dependent on local migration, registering more than thirty percent of their in-migrants from within their respective counties (Figures 7a–7b).

Our data suggests a correlation between distance traveled per new migrant and urban growth rates. In the nineteen high-growth cities the average distance traveled per migrant was 462km, nearly 100km farther than in the slower growing cities. Broken down by region, these differences come into still sharper relief. For the less accessible western states, where migrants from the rest of Brazil must travel farther, new migrations to the region's faster growing cities averaged 550km, 150km more than in slower growing cities. For Pará, which is located closer to the densely populated State of Maranhão, the difference was far less, at 362 to 320km. In Mato Grosso, the average migrant to one of the state's high-growth mid-size agricultural cities traveled an average of 582km, or nearly 200km farther than migrants to Barra do Garças, Alta Floresta, or Cáceres. Lucas do Rio Verde ranked first among all cities in the basin in attracting migrants traveling the greatest distance, with the average migrant traveling nearly 900km. Faster growing cities, on average, were drawing in a larger percentage of new migrants from out of the Amazon, and a lower percentage of migrants from within their respective state (Figures 6a–6b). In general, urban growth is negatively related to the proportion of new residents from in state, and positively to the proportion of new residents from out of state.

Migrants' Backgrounds

For information on new migrants' motivations to move and prior backgrounds we turn to household level data from Lucas do Rio Verde, in Mato Grosso, and Santarém and Altamira, of western and central Pará State. Lucas do Rio Verde, an agricultural city that has grown from a small village in the 1980s to a prosperous city boasting downstream processing facilities for agricultural commodities, was discussed in the previous section. Santarém is a low-growth, mid-sized city. Located at the confluence of the Amazon River and one of its major tributaries, the Tapajós, it has been continuously settled since pre-Columbian times, though the city traces much of its modern day structure and population to the rubber boom (D'Antona, VanWey and Hayashi 2006). In the past decade, or since the construction of a Cargill-operated deep water port for soybeans (most of which arrive by barge from a receiving facility at Porto Velho, in Rondônia), the city has experienced a brief boom in soybean production; however, farmers here are isolated and environmental concerns have dampened prospects for future agricultural growth (Garrett et al. 2013b).

Altamira differs from both Lucas do Rio Verde and Santarém. Altamira was one of Brazil's first large-scale, planned colonization initiatives in the Amazon. First conceived in the late 1960s as the urban anchor to a large agricultural colony and as a keystone to a large, pan-Amazon development plan, Altamira grew rapidly in terms of both rural and urban population during the 1970s through to the 1980s (Umbuzeiro 1981, Moran, Brondizio and

VanWey 2005, VanWey, Guedes and D'Antona 2012). Economically, Altamira has been dominated by cattle production and the cultivation of cacao or other fruit crops. The recent development of the Belo Monte dam, approximately thirty kilometers east of the city, has also brought new economic activity and new residents to the region.

We draw on household surveys collected from 2009–2012 in these three cities to better understand the motivations underlying the migration process. The household surveys show motivations for migration, origin locations, and past experiences and previous living situations. Our analysis spans the origins and motivations of male and female household heads, or of approximately 900 individuals in each of the three study sites.

The survey responses reflect each city's respective age. In Lucas do Rio Verde, the youngest of the three cities, most residents arrived to the city over the past twenty years. In Santarém and Altamira, this figure is far less, between one-tenth and one-sixth of respondents of these cities, respectively, arrived since 1990 (Table 1). The motivations underlying in-migration to these cities also vary, both between cities and over time. In Lucas do Rio Verde, a steady and increasing majority of migrants to the city migrated for employment. Most migrants to Santarém, in contrast, cited family or other reasons (e.g., access to services) rather than for employment. Altamira represents a middle ground between the two cities.

Not only were more residents migrating to Lucas do Rio Verde for employment reasons, they were also more likely to do so from other urban areas. Our survey data indicates that consistently, more than half of the new residents to the city had arrived from other urban areas. In Santarém, this percentage is far lower, with more than half having arrived from rural regions, suggesting that for many rural families Santarém was the first stop in the rural-urban migration process. These findings are in close agreement with ethnographic work in the region indicates that the city is absorbing population from its surrounding rural areas (Macdonald and Winklerprins 2014). Altamira again represents a middle ground in this regard, though in the past decade nearly three-quarters of new residents arrived from urban regions, a percentage roughly in line with that of Lucas do Rio Verde.

There are also clear temporal trends embedded within the data. Most notably, each survey indicates a temporal trend toward more urban migrants, and more migrants moving for employment reasons than family purposes. When the reasons for migrating are broken down according to rural and urban residents, more urban-urban migrants move for employment reasons than for family or other factors (not shown). Evidently, cities such as Lucas do Rio Verde are tapping new migrants arriving not from agricultural backgrounds seeking better access to the services provided in urban areas, but rather migrants arriving from urban locations, and from states located across Brazil.

We draw two principal conclusions from the survey results. First, the majority of growth in the these cities, and in particular in the most recent years, has come through the addition of new migrants from other areas. Second, the Amazon's cities are receiving more urban than rural migrants with each year, and that these arrivals are increasingly arriving not for family reasons or for the amenities of the city but for employment reasons.

Discussion and Conclusion

The Brazilian Amazon is heterogeneous in its landscapes, population, and biophysical characteristics. However, several contextual commonalities tie together the locations of rapid urban growth in the Amazon. We highlight these ties in this section, then extend our discussion to consider the broader implications of this work and question to what extent the current model of economic growth is sustainable.

Urbanization and access to rural resources

Urban growth in the Amazon is tied to access to both resources and export facilities. In nearly every case of rapid growth a city was closely positioned to a production or extraction point for food or natural resources. Additionally, in these cities the principal, rent generating resource was primarily consumed externally. Not coincidentally, it follows that each of these cities is also located along one of the Amazon's export corridors. In Mato Grosso, the fastest growing agricultural cities are positioned along the state's principal highway corridors, with (relative to the region) adequate access to export ports on the Atlantic coast. In Pará, the iron rich city of Parauapebas is connected by rail to deep water ports on the Atlantic, while the rest of its fast growing cities are located along the framework of federal highways that continue to represent the state's principal export corridors. In contrast, the river cities of the Amazon, scattered along the highway of times past, have grown at slower rates. The one exception to this rule is the city of Oriximiná, which, however, is somewhat exceptional in its ability to leverage its combination of bauxite reserves and deep water port access to capture and sustain its population and economic growth.

A second commonality that spans the faster growing cities is the magnitude of production investments. Today, agriculture in Mato Grosso is highly capitalized, and the region's agricultural expansion represents the enormous costs of machinery, silo and storage infrastructure, research and extension need for production, as well as the clearing and preparing of croplands from forest areas. Hydroelectric and mineral operations also represent significant investments, whether from the public or private sector, and will continue to generate economic returns. Even the cattle sector, which is a generally known as a low cost industry, is now supported by a network of slaughterhouses and refrigeration plants spanning across Mato Grosso and southern and central Pará. Each of these facilities is a multi-million dollar investment, and supports a significant, generally urban-based work force. Nearly every faster growing city has benefited from one or several of these major investments, whether in publically financed energy or transportation projects, in private, farm-level investments in agricultural machinery and land clearing, or through corporate investments in ports or mine infrastructure. More broadly, we find that in many of these faster growing cities public investments in infrastructure have accompanied the recent urban and economic growth. Perhaps this is clearest in Mato Grosso, where the rapidly growing soybean cities have added and expanded universities, have extended the region's network of paved roads, and sought the regularization of land titles.

A third commonality that persists across nearly all of these cities is the relative sustainability of resource access. Agriculture will likely constitute a sustainable base for economic activity and rent generation for years to come, a prospect that will continue to challenge theoretical

frameworks that fail to recognize the role of agriculture as a driver of urban growth in the Amazon, as well as the conceptualization of the Amazon's new urban areas as intrinsically linked to the consumption and depletion of natural resources. Unlike timber or gold, which are quickly depleted, agriculture produces annual harvests. Similarly, the vast mineral deposits of Carajás and Juruti (bauxite) should sustain production for generations to come. However, while the extraction of these resources may be sustainable, it should be observed that their relative impact on urban growth or socioeconomic development will be inextricably tied to returns to agriculture or mineral extraction. Over the past decade, with the devaluation of the real and the economic crisis of 2008, returns to food and material exports, have on average, been favorable. However, there is no guarantee that economic conditions will continue to favor the production of export goods, though projections suggest that demand for food crops such as soybeans should be high for the coming decade (ICONE 2012).

Finally, we call attention to a final contextual commonality spanning the faster growing cities, namely the lower density of rural labor. In the Amazon, the fastest growing cities are not only located in close geographic proximity to resource riches, but they benefit from institutional conditions that facilitate the extraction and commercialization of traded commodities. In Mato Grosso, for example, large property sizes and clear titles enable soybean production. We also recognize that urban growth in the Amazon is not a function of small farmers discarded to the economic turmoil of the urban periphery. In fact, we find that urban growth is occurring in the midst of the wealthiest rural regions, and in correlation to agricultural intensification. Densely populated rural regions may in fact thus be negatively correlated with urban growth, as rural populations will absorb rural rents rather than transfer them to urban consumptions.

Urban growth and global teleconnections, and rethinking the rural-urban relationship

The dependence of urban growth in the Amazon on globally traded, rurally produced commodities such as beef, soybeans, or iron extends our understanding of the social dimensions of global land use telecouplings (Lambin and Meyfroidt 2011, Lambin and Liu 2014). Research to date has often focused on the social drivers, including urbanization, that drive global land use change (DeFries et al. 2010). Other research has asked how urban growth and economic changes influence local agricultural practices (Jiang, Deng and Seto 2013). In our work we seek to reframe this discussion by broadly recognizing that not only are global changes in consumption reshaping land use change in the developing world, but that they are also, in turn, driving further urbanization.

Conceptualizing urban growth as a function of rural changes, even potentially distant changes in rural land use, has precedent in the geographic literature. Notably, Peet (1969), argued that the development of the American Midwest as an agricultural heartland indirectly contributed to urbanization and industrialization in both the northeast US and in northern Europe. Cronon (1991) argued that the same process also gave rise to the prominent cities that today dominate the American Midwest. Presently, Brazil is forging a similar trade relationship with the rapidly industrializing nations in East Asia, and supplying raw materials and food goods to Asia in return for manufactured items. In this sense, Brazil now

constitutes a new global rural, providing its resources to the labor-rich factories of Asia. Thus iron from Parauapebas is smelted in steel yards in China, by a manufacturing labor force consuming pork and poultry fattened on Brazilian soybeans (Baldwin 2011). Yet the social and economic benefits or impacts of this relationship run two ways. For in Brazil, resource rents are now feeding urban growth, even in the Amazon. The result is a residual, feedback urbanization process that is now reaching the once marginalized regions of central and northern Brazil. However, the Amazon's current urban growth is dangerously dependent on exogenous external markets, rather than endogenous or national demand for locally produced goods. Its continued growth will therefore depend on the continued growth in the demand for exports, and on prices set on commodity exchanges. This leads to a final question, and by which we close our article, namely is such a model of urban growth sustainable?

Will Resource-Based Urban Growth be Sustainable?

The dependency of urban growth in the Amazon on external markets and demand for basic commodities, and increasingly on a supply chain that ships to Asia, is vaguely suggestive of the specter of the unilateral dependency that led to the collapse of the rubber era during the 1920s. However, while recognizing that urban growth in the Amazon may well be contingent on continued growth in the industrializing Asian nations, the present day Amazon urban centers, and the economy of the region more broadly, are buffeted by several factors. First, if many of the region's principal exports are shipped through the same ports or waterways, the actual products are diverse, and each is subject to its own market. Second, growth in production has come with immense investments in productive capacity. In the case of the agricultural and cattle sectors, boom years in agricultural prices not only ensured a higher demand for local services but also resulted in new investments in this region, from new ports and paved roads, to new land clearings that further increased the region's agricultural output. When paired with the magnitude of the region's natural resource reserves, these investments should ensure the production or extraction of rural capital for decades to come. The result, in cities across the Amazon, is an economic future that, while dependent on resource global prices and demand for resource commodities, will be sustained by the enormity of the region's reserves of land, mineral, and hydrologic resources.

We close by arguing that the last two decades of urban and economic growth in the Amazon have already consolidated the region's place in the global marketplace as more than a subsidized outpost in geopolitical conquest. The region's tropical treasures in mines and fertile agricultural land, now harnessed, will have the power to greatly influence the trajectory of Brazil's economic growth and to satisfy global demand for the food and resources for the coming century. The Amazon appears poised for further urban growth, but its sustainability will depend on exogenously determined markets and economic shocks, and the region's ability to continue to capture resource rents before they are permanently and irreversibly extracted from the region.

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APPENDIX

Table A1

List of Mid-Size Cities

			Population		%Change
	Name	**State**	**2000**	**2010**	**2000–2010**
1	Santarém	PA	186297	215790	16%

			Population		%Change
	Name	**State**	**2000**	**2010**	**2000–2010**
2	Rondonópolis	MT	141838	188028	33%
3	Marabá	PA	134373	186270	39%
4	Parauapebas	PA	59260	138690	134%
5	Ji-Paraná	RO	91013	104858	15%
6	Sinop	MT	67706	93753	38%
7	Tucuruí	PA	60918	92442	52%
8	Altamira	PA	62285	84092	35%
9	Cáceres	MT	66457	76568	15%
10	Ariquemes	RO	55118	76525	39%
11	Paragominas	PA	58240	76511	31%
12	Tangará da Serra	MT	51495	75921	47%
13	Bragança	PA	56572	72621	28%
14	Vilhena	RO	50601	72218	43%
15	Itaituba	PA	64486	70682	10%
16	Redenção	PA	59613	70065	18%
17	Parantins	AM	58125	69890	20%
18	Cacoal	RO	51398	61921	20%
19	Manacapuru	AM	47662	60174	26%
20	Tailândia	PA	28128	58713	109%
21	Sorriso	MT	31529	58364	85%
22	Itacoatiara	AM	46465	58157	25%
23	Cruzeiro do Sul	AC	38971	55326	42%
24	Cametá	PA	40417	52838	31%
25	Barra do Garças	MT	47843	50947	6%
26	Capanema	PA	46329	50947	10%
27	Tefé	AM	47698	50069	5%
28	Coari	AM	39504	49651	26%
29	Primavera do Leste	MT	36539	49271	35%
30	Breves	PA	40285	46560	16%
31	Jacundá	PA	34518	45683	32%
32	São Félix do Xingu	PA	12530	45113	260%
33	Alta Floresta	MT	37287	42718	15%
34	Lucas do Rio Verde	MT	16145	42455	163%
35	Rolim de Moura	RO	34421	41429	20%
36	Oriximiná	PA	29181	40147	38%

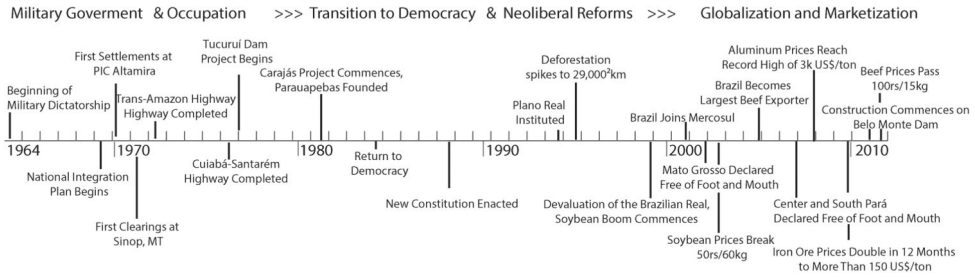

Figure 1.
Timeline of events significant to the urban and rural redefinition of the Amazon

Figure 2.
Amazon States of Brazil

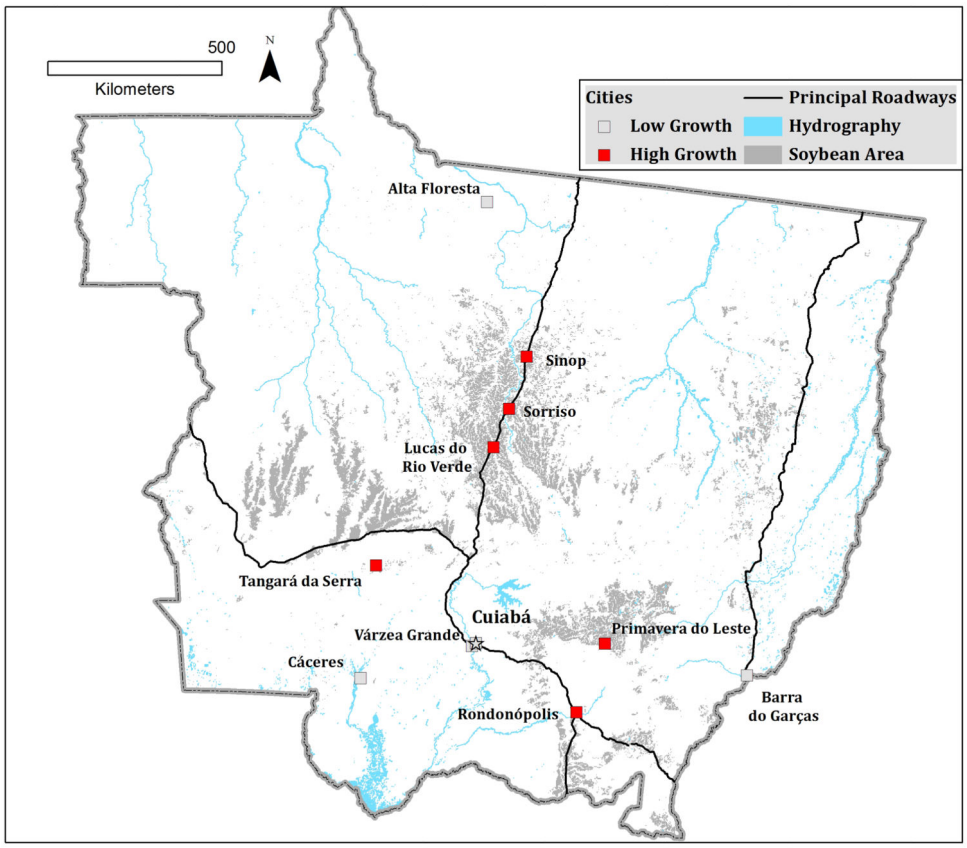

Figure 3.
High and Low-growth Cities and Cropland in Mato Grosso

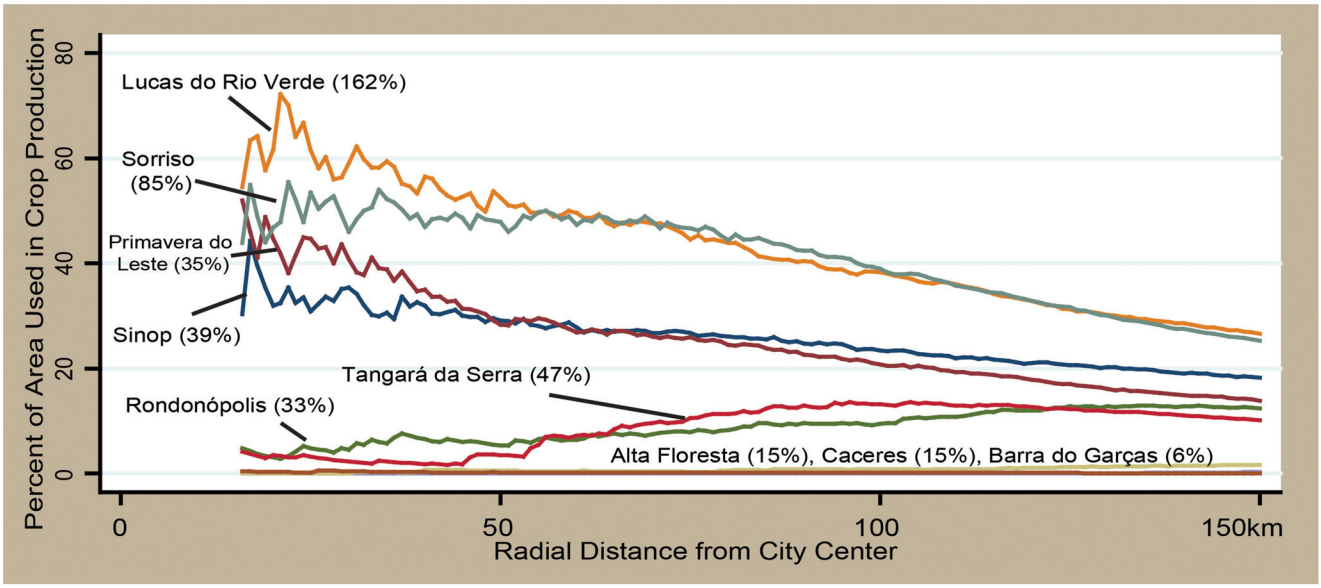

Figure 4.

Total percent of area planted with soybeans, by radial distances from city center. Rates of population growth are shown in parentheses. Data based on estimates derived from MODIS satellite imagery (Spera et al. 2014).

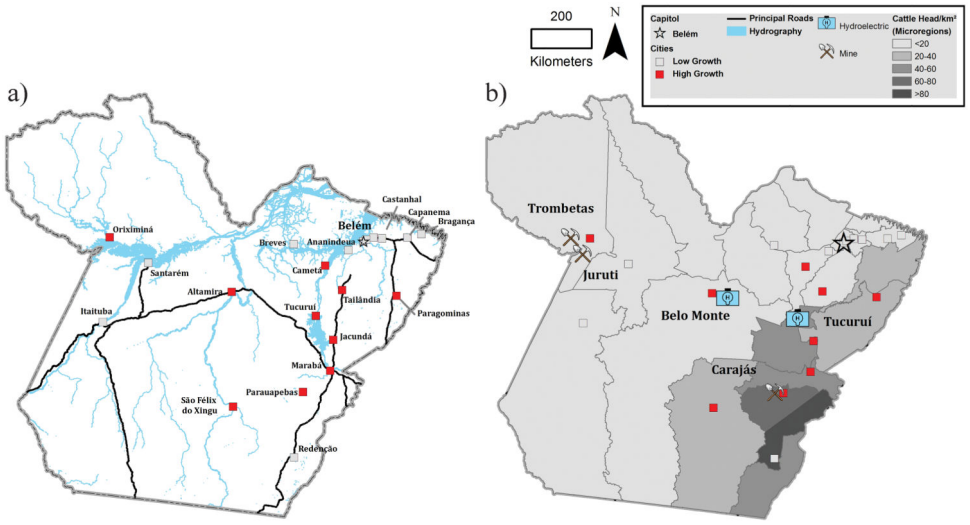

Figure 5.

Figures 5a and 5b. 5a: High and Low-growth Cities in Pará. 5b Cattle herd density (by micro-region), principal mineral

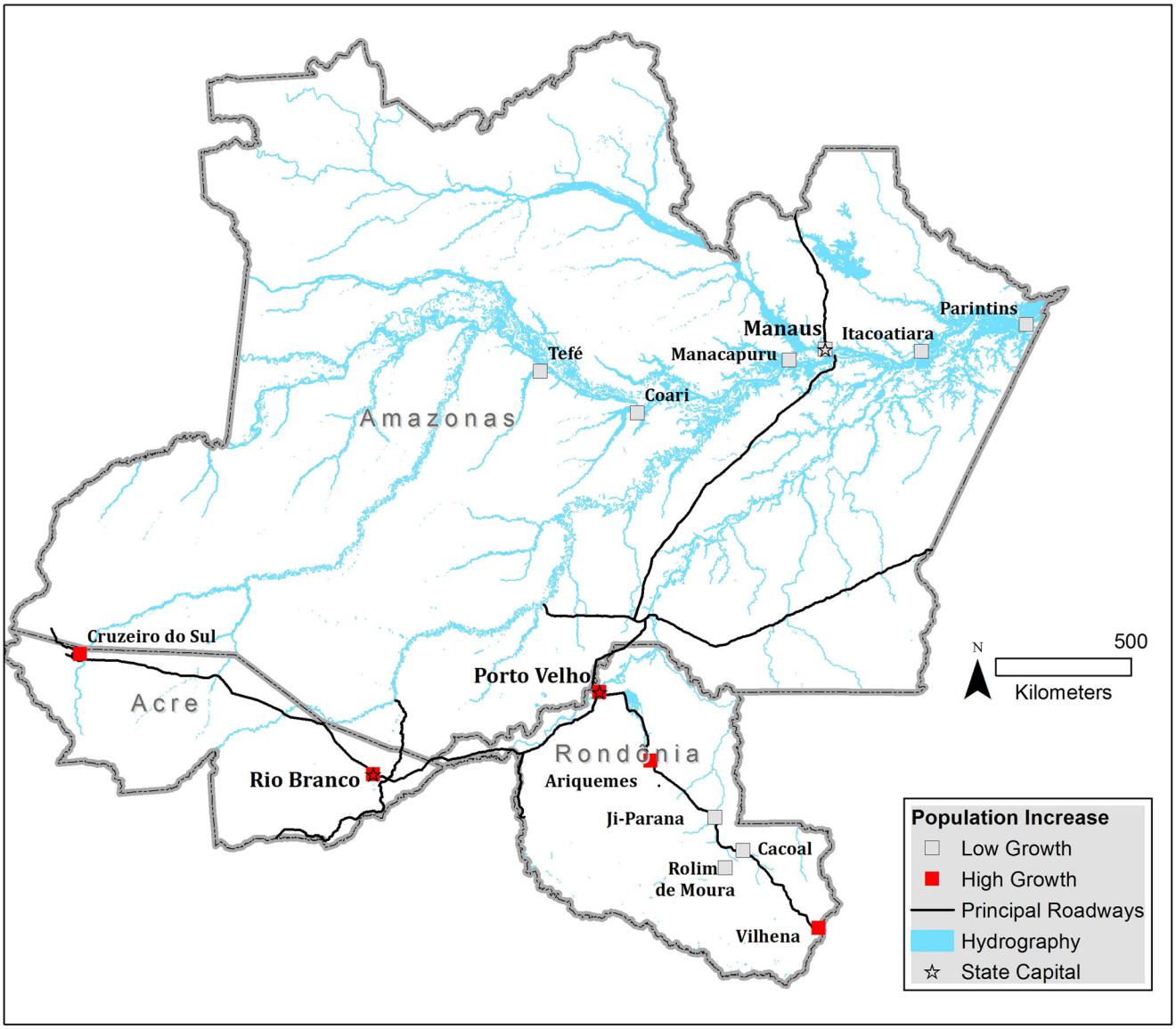

Figure 6.
The Western Amazon States and cities

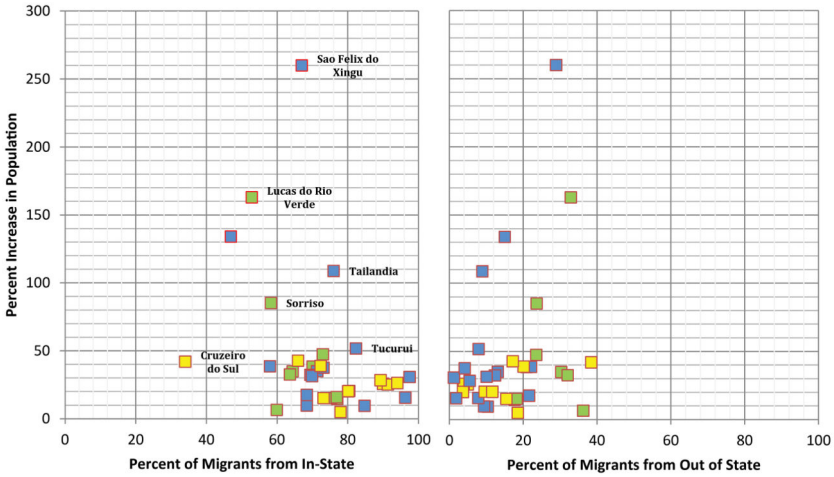

Figure 7.

Figures 7a–7b. Percent of new residents from in and out of state Green points indicate cities in Mato Grosso; Blue: Pará; Yellow: western Amazon States

Table 1

Percent of Migrants by Period of Arrival

Total n	**N =890**	**N= 990**	**N=984**
Year of Arrival	**Lucas**	**Santarém**	**Altamira**
2005–2009	32	6	10
2000–2004	22	5	7
1995–2000	13	5	6
1990–1995	9	6	8
Pre 1990	24	63	54
Born Here	.1	15	16

Table 2

Table 2a. Reasons for moving to the city. Does not include residents born in site. Figures are by percent.

	Lucas do Rio Verde			Santarém			Altamira		
	Empl	**Fam/Hea**	**No Ans**	**Empl**	**Fam/Hea**	**No Ans**	**Empl**	**Fam/Hea**	**No Ans**
2005–2009	74	25	0	42	58	0	44	55	0
2000–2004	62	37	0	38	58	4	48	53	0
1995–1999	58	41	0	55	45	0	34	66	0
1990–1995	46	53	0	31	69	0	20	80	0
Pre 1990	39	43	16	17	41	42	19	52	28
Totals (%)	**58**	**28**	**4**	**23**	**45**	**32**	**26**	**56**	**18**
Total (n)	523	328	38	197	380	262	212	467	150

Table 2b. *Prior location: rural or urban districts.*

	Rur	Urb	No Ans/NA	Rur	Urb	No Ans/NA	Rur	Urb	No Ans/NA
2005–2009	14	79	6	41	58	2	24	76	0
2000–2004	21	74	5	42	54	4	25	75	0
1995–1999	31	64	5	63	33	4	50	50	0
1990–1995	33	68	0	58	40	2	51	49	0
Pre 1990	25	59	16	42	30	29	34	37	29
Totals (%)	**22**	**71**	**8**	**44**	**34**	**22**	**34**	**47**	**19**
Total (n)	195	627	67	369	287	185	285	389	155