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

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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. *Key Words:* Brazilian Amazon, development, urban growth.

将亚马逊发展成为国际矿产贸易与粮食商品的主要供应者，已戏剧性地将广大的热带森林，转变成农田、牧场与矿区。此一转变的环境冲击，以及该过程的根本驱动力，已有详尽的纪录。我们在本文中，将分析视角转向亚马逊土地使用及环境变迁的其他较少受到检视之影响，亦即新城市地区的创造及发展。我们于此主张，亚马逊的城市成长，是国际对贸易商品生产的兴趣，以及城市在地居民在资本与价值自本区榨取出之前，捕捉该价值之能力的直接残馀。我们特别主张，在同时能够获得农村出口商品和出口管道的城市中，城市成长最为快速。我们同时展现出城市成长和较低的人口密度，以及城市从其直接的周遭农村之外吸引移民的能力之间的相关性。更广泛而言，我们主张亚马逊的城市化，最好能够诠释为该区域土地使用和土地覆盖变迁的徵兆、而非其驱动力。 *关键词：* 巴西亚马逊地区，发展，城市成长。

El intento por convertir la Amazonia en una importante fuente de productos minerales y alimentarios para el comercio internacional ha transformado dramáticamente vastas extensiones de la selva tropical en tierras de cultivo y pastoreo, y minas. Los impactos ambientales de esta transformación, lo mismo que los factores que está detrás del proceso, ya han sido bien documentados. En el presente artículo orientamos nuestra visión analítica hacia un efecto menos estudiado del cambio ambiental y de uso del suelo amazónico, cual es la fundación y desarrollo de nuevos lugares urbanos. En este trabajo nosotros sostenemos que el crecimiento urbano en la Amazonia es un directo residuo del interés internacional en la producción de bienes comerciales y de la capacidad de los residentes urbanos locales de capturar capital y valor antes de que éstos sean extraídos de la región. Específicamente, sugerimos que el crecimiento urbano está ocurriendo con mayor celeridad donde las ciudades ganan acceso tanto a los productos rurales exportables como a los corredores de exportación. También mostramos correlaciones entre el crecimiento urbano y la menor densidad de población rural, y las capacidades de las ciudades para atraer migrantes desde fuentes migratorias diferentes a sus alrededores rurales próximos. Ampliando el argumento, sostenemos que la urbanización de la Amazonia se puede interpretar mejor como síntoma que como la impulsora del cambio en el uso y cobertura de la tierra. *Palabras clave:* Amazonia brasileña, desarrollo, crecimiento urbano.

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 on 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 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 reevaluate 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. Since the 1990s, however, 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. More so than ever before, the benefits of these investments are staying, in the form of economic growth, rising socioeconomic indicators, 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. 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. We also 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. Although 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 (Eakin et al. 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 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, whereas 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, 2012; Rudel, Bates, and Machin-guiashi 2002; Grau et al. 2003), 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, as a consequence, losses in biodiversity and new carbon emissions (Seto, Güneralp, and Hutyrá 2012). In this research we fully acknowledge this scenario but recognize that under certain scenarios cities might 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. **We argue, however, 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 sectoral 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 micropolitan (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 recirculate 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 reconceptualization 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 twentieth 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 (1997) influential volume on urbanization in the Amazon, *Rainforest Cities*.

In *Rainforest Cities*, Browder and Godfrey (1997) 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 (e.g., 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 of 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). 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). 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). 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, although 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, Browder, et al. 2009). Falling transportation costs to the Amazon, combined with record high prices in Brazil for traded commodities such as soybeans (in 2002, 2004, and 2012), beef (2004, 2008, and 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. A principal difference between the present-day commodity boom and the boom and bust cycles of time past, however, resides in the relative spatial concentration of extractable value and capital investments in the

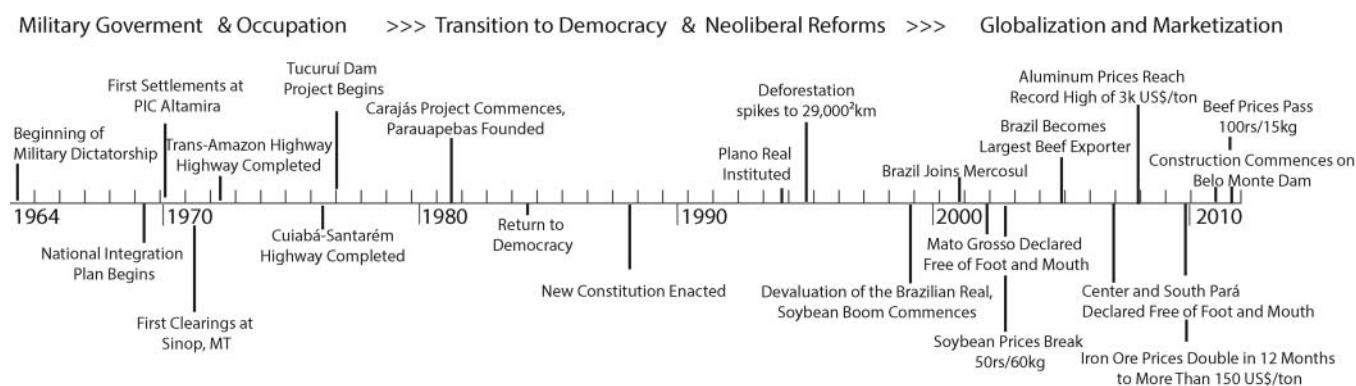


Figure 1. Timeline of events significant to the urban and rural redefinition of the Amazon.

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 seventeenth-century Jesuit missions and late nineteenth-century rubber collection points and telegraph posts (which includes many of the Amazon states' present-day capitals), to mid-twentieth-century colonization plans under Brazil's military dictatorship, and to the twenty-first-century commodity boom. The oldest cities are located on the main channel of the Amazon; others are found 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 *midsized cities*, or those noncapital 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 that differ tremendously in terms of settlement patterns and demographics from the rest of the Legal Amazon¹ (see Figure 2) and all capital or capital metro area cities.² We thus focus on thirty-six cities across Mato Grosso (nine), Pará (sixteen), Acre (one), Rondônia (five), and Amazonas (five). A list of these cities is included in the Appendix. Nineteen of these cities have grown at rates of more than 30 percent between the 2000 and 2010 censuses; seventeen have grown at slower rates (Instituto Brasileiro de Geografia e Estatística [IBGE] 2000, 2010a). 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.



Figure 2. Amazon states of Brazil. (Color figure available online.)

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, Browder, et al. 2009). 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, 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 noncapital cities in Mato Grosso with population greater than 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

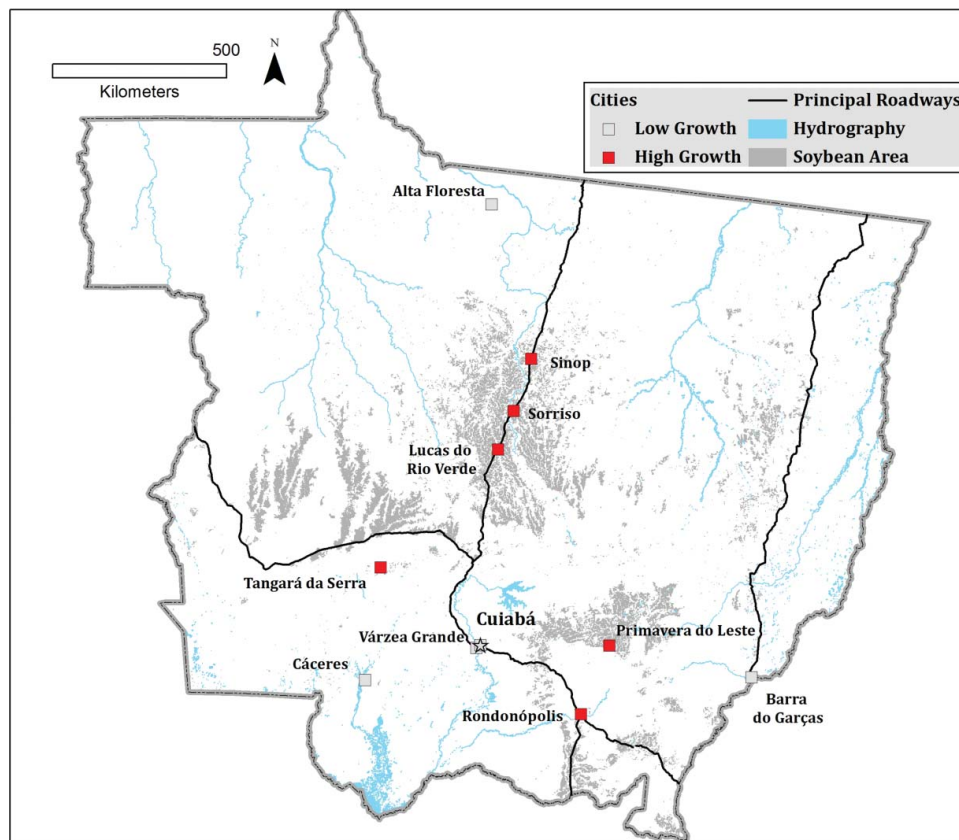


Figure 3. High- and low-growth cities and cropland in Mato Grosso. (Color figure available online.)

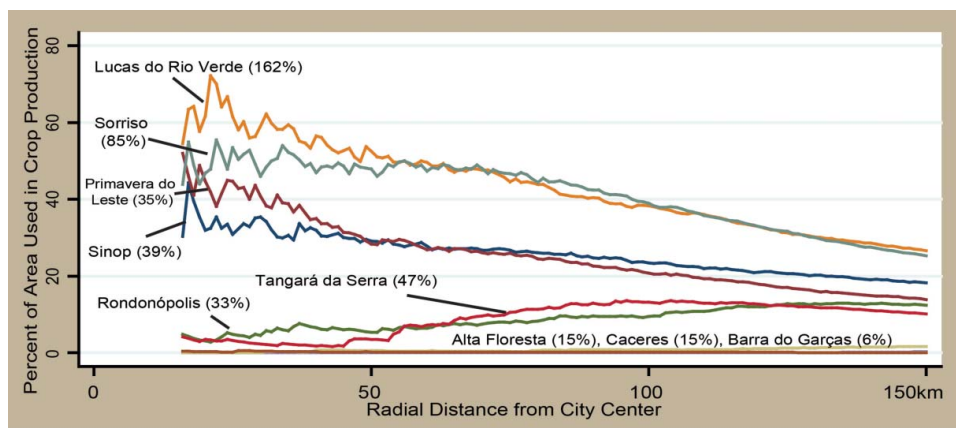


Figure 4. Total percentage of area planted with soybeans, by radial distances from city center. Rates of population growth are shown in parentheses. *Source:* Data based on estimates derived from MODIS satellite imagery (Spera et al. 2014). (Color figure available online.)

region's soybean sector. Elsewhere, Primavera do Leste and Rondonópolis 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 grown by more than 30 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 and economic growth and exhibited some of the lowest growth rates not only in Mato Grosso but for midsize 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 is 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 nonagricultural cities (IBGE 2006). The presence of landowners within the local city ensures not only 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 (Programa das Nações Unidas para o Desenvolvimento [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

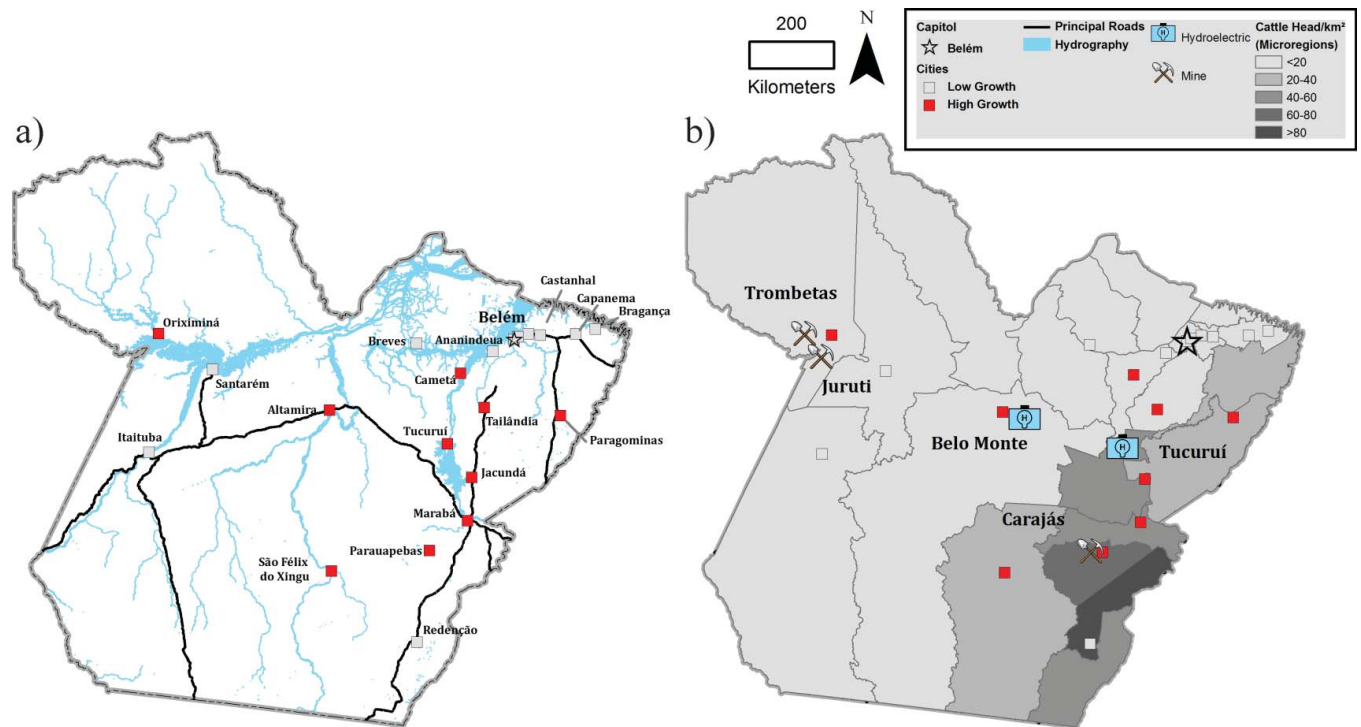


Figure 5. (A) High- and low-growth cities in Pará. (B) Cattle herd density (by microregion), principal mineral. (Color figure available online.)

(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), and Oriximiná includes multiple bauxite mines.

In Parauapebas, urban population growth has been rapid since the 1980s, but the growth rate has accelerated since 2000. From 1991 to 2000, Parauapebas grew approximately 4 percent per year. Since the millennium, though, this rate has increased to approximately 11 percent per year, making it one of the fastest growing cities in Brazil. Not coincidentally, iron ore prices, which stagnated at less than US\$15 per metric ton from the 1980s through the early 2000s, increased to historic highs in the late 2000s, cresting at nearly US\$200 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. Although 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, corresponds to megainvestments in hydroelectric facilities. The 8,000 MW Tucuruí facility on the Tocantins River is among the largest in the country (Browder and Godfrey 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 (population 92,000) and Altamira (84,000) both rank among the fastest growing urban areas in Pará, adding more than 30,000 and 20,000 in population, respectively, 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, Moran, and Anselin 2000). Over the past decade, however, 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, Stickler, and Almeida 2006; Walker, Browder, et al. 2009). 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 6 million animals. The São Felix do Xingu, Tucuruí, and Altamira micro-regions each registered gains of more than 1.5 million animals (Figure 5). 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 do Xingu, 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 30 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. The south of Pará is rich in three primary resources to the beef sector, however: the precipitation; extensive, affordable land suitable for pasture; and a tropical climate favorable to Nelore 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 faster than 30 percent over the past decade: Vilhena and Ariquemes in Rondônia, and Cruzeiro 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. From 2000 to 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, and the *garimpo bom futuro*,

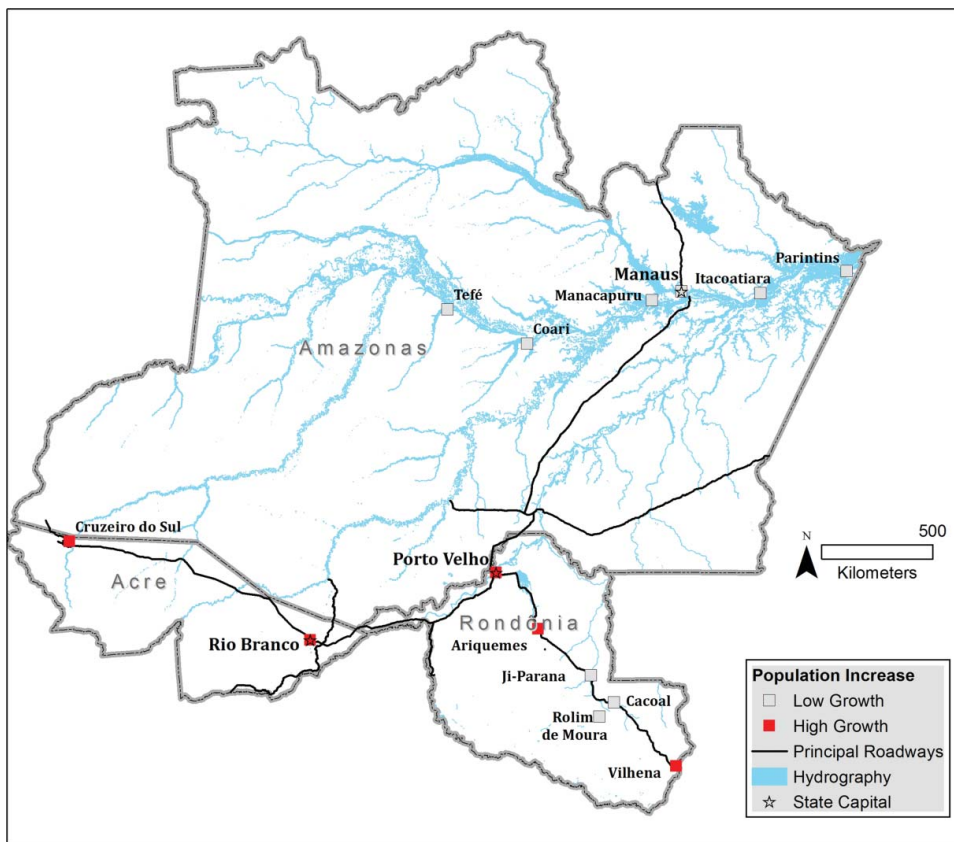


Figure 6. The Western Amazon states and cities. (Color figure available online.)

perhaps the largest complex of open air gold sites in the world, lies less than 50 km 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 30 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 integration and development hubs. The city has grown to more than 55,000, an increase of more than 40 percent in the past decade and double 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 immigrants to the Amazon's interior cities, and migrants' backgrounds.

Population Density

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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 ($N \sim 16,000$ 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. Although 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 data set contains a relatively limited base of information. In this section we thus focus on only three principal points of analysis: (1) population density, (2) percentage 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 1-km intervals for up to 50 km (average levels remain stable over 50 km); 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 R1,500/month (about US\$1,000 in 2010), or several hundred 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 2010b). These statistics suggest that the fastest growing urban areas are surrounded by relatively profitable but sparsely populated rural areas. This is in contrast to the declining marginal utility of labor in the traditional theoretical models of rural outmigration (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 might 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

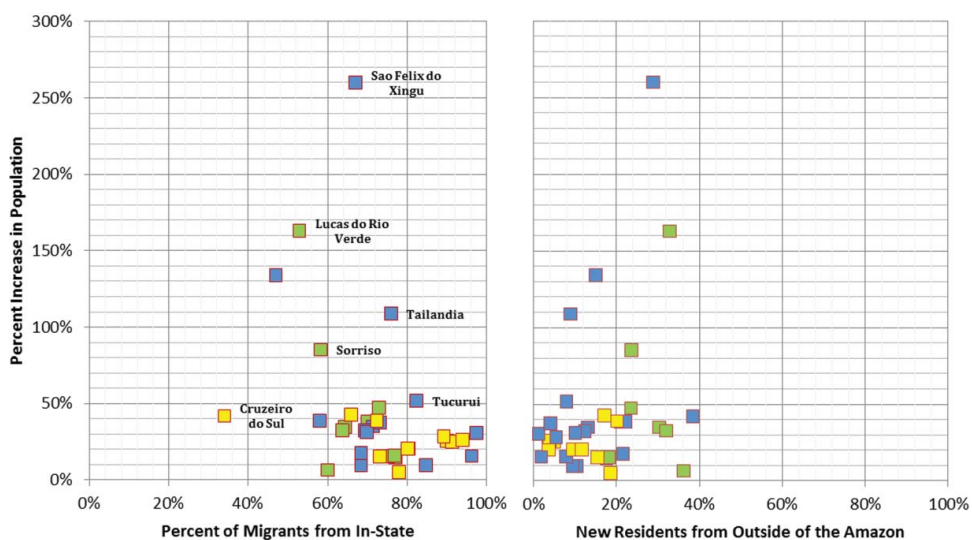


Figure 7. Percentage of new residents from (A) in state and (B) states outside of the Legal Amazon. Green points indicate cities in Mato Grosso; blue represents cities in Pará; yellow indicates Western Amazon states. (Color figure available online.)

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 could 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, and recent work by da Costa and Brondízio (2009) recognized the importance of interurban linkages as an influence underlying the location and extent of urban growth. Here we consider source locations of immigrants to midsize cities through sample data, equivalent to the U.S. 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 geographic information system. 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 suggest 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 percent), 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 30 percent of their in-migrants from within their respective states (Figures 7A and 7B).

Our data also suggest 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 462 km, nearly 100 km 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 a distance of 550 km, 150 km 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 km to 320 km. In Mato Grosso, the average migrant to one of the state's high-growth midsize agricultural cities traveled an average of 582 km, or nearly 200 km 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 900 km. Faster growing cities, on average, were drawing in a larger percentage of new migrants from outside of the Amazon and a lower percentage of migrants from within their respective state. In general, urban growth is negatively related to the proportion of new residents from in state and positively related 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, although the city traces much of its modern 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, Lambin, and Naylor 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 larger, pan-Amazon development plan, Altamira grew rapidly in both rural and urban population during the 1970s and 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 30 km east of the city, has also brought new economic activity and new residents to the region.

We draw on household surveys collected from 2009 to 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, as between one tenth and one sixth of respondents of these cities, respectively, arrived since 1990 (Table 1). The motivations underlying immigration 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 health services) rather than employment. Altamira represents a middle ground between the two cities (Table 2).

Not only were more residents migrating to Lucas do Rio Verde for employment reasons, but they were also more likely to do so from other urban areas. Our survey data indicate 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 (Table 3). These findings are in close agreement with ethnographic work in the region that 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, although 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.

Table 1. Percentage of migrants by period of arrival

Year of arrival	Lucas ^a	Santarém ^b	Altamira ^c
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	0.1	15	16

^aN = 890.

^bN = 990.

^cN = 984.

Table 2. Reasons for moving to the city

	Lucas do Rio Verde			Santarém			Altamira		
	Employment	Family/health	No answer	Employment	Family/health	No answer	Employment	Family/health	No answer
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	34	4	23	45	32	26	56	18
Total (n)	523	328	38	197	380	262	212	467	150

Note: Does not include residents born in site. Figures are by percentage.

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 these cities, and in particular in the most recent years, has come through the addition of new migrants from other urban areas. Second, the Amazon's cities are receiving more urban than rural migrants with each year, and 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, but several contextual commonalities tie together the locations of rapid urban growth in the Amazon. We highlight these ties in this section and 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

Table 3. Prior location: Rural or urban districts

	Lucas do Rio Verde			Santarém			Altamira		
	Rural	Urban	No answer/NA	Rural	Urban	No Answer/NA	Rural	Urban	No answer/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

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, and 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 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 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 multimillion-dollar investment and supports a significant, generally urban-based workforce.

Nearly every faster growing city has benefited from one or several of these major investments, whether in publicly 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, 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. Although the extraction of these resources might 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. There is no guarantee, however, that economic conditions will continue to favor the production of export goods, although 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 with agricultural intensification. Densely populated rural regions might, 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; Eakin et al. 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 U.S. Midwest as an agricultural heartland indirectly contributed to urbanization and industrialization in both the U.S. Northeast and in northern Europe. Cronon (1991) argued that the same process also gave rise to the prominent cities that today dominate the U.S. 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. 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. The Amazon's current urban growth, however, 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 with which we close our article: 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 we recognize that urban growth in the Amazon could 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, although 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 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.

Notes

1. 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 percent of Brazil's territory, including all of the Amazon biome (in Brazil).
2. For example, in Mato Grosso, Várzea Grande is across the River Paraguay from the capital Cuiabá. Cities classified as capital suburbs include Várzea Grande, MT; Santana, AP; Santa Isabel do Pará, PA; Castanhal, PA; Abaetetuba, PA; and Ananindeua, PA.

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Appendix. List of midsize cities

	Name	State	Population		% change 2000–2010
			2000	2010	
1	Santarém	PA	186,297	215,790	16
2	Rondonópolis	MT	141,838	188,028	33
3	Marabá	PA	134,373	186,270	39
4	Parauapebas	PA	59,260	138,690	134
5	Ji-Paraná	RO	91,013	104,858	15
6	Sinop	MT	67,706	93,753	38
7	Tucuruí	PA	60,918	92,442	52
8	Altamira	PA	62,285	84,092	35
9	Cáceres	MT	66,457	76,568	15
10	Ariquemes	RO	55,118	76,525	39
11	Paragominas	PA	58,240	76,511	31
12	Tangará da Serra	MT	51,495	75,921	47
13	Bragança	PA	56,572	72,621	28
14	Vilhena	RO	50,601	72,218	43
15	Itaituba	PA	64,486	70,682	10
16	Redenção	PA	59,613	70,065	18
17	Parantins	AM	58,125	69,890	20
18	Cacoal	RO	51,398	61,921	20
19	Manacapuru	AM	47,662	60,174	26
20	Tailândia	PA	28,128	58,713	109
21	Sorriso	MT	31,529	58,364	85
22	Itacoatiara	AM	46,465	58,157	25
23	Cruzeiro do Sul	AC	38,971	55,326	42
24	Cametá	PA	40,417	52,838	31
25	Barra do Garças	MT	47,843	50,947	6
26	Capanema	PA	46,329	50,947	10
27	Tefé	AM	47,698	50,069	5
28	Coari	AM	39,504	49,651	26
29	Primavera do Leste	MT	36,539	49,271	35
30	Breves	PA	40,285	46,560	16
31	Jacundá	PA	34,518	45,683	32
32	São Félix do Xingu	PA	12,530	45,113	260
33	Alta Floresta	MT	37,287	42,718	15
34	Lucas do Rio Verde	MT	16,145	42,455	163
35	Rolim de Moura	RO	34,421	41,429	20
36	Oriximiná	PA	29,181	40,147	38

Note: PA = Para; MT = Mato Grosso; RO = Rondônia; AM = Amazonas; AC = Acre.