Land Use Policy 90 (2020) 104327

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

The construction of the Belo Monte dam in the Brazilian Amazon and its consequences on regional rural labor

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ARTICLE INFO

Keywords:
Amazon
Hydroelectric dams
Socioeconomic impacts
Labor mobility
Agropastoral activities

ABSTRACT

The article analyzes the impacts of the Belo Monte dam construction on the rural labor mobility dynamics and the effects on the agropastoral activities, in the rural areas of the Altamira region, Pará state, in the Brazilian Amazon. The study is based on longitudinal data organized as a panel survey applied to fixed sample of 402 rural properties for each survey in the years of 1997/98, 2005 and 2015. The construction of Belo Monte dam produced a demographic boom in Altamira, with the urban population almost doubled during the construction period between 2011 and 2014. The increased demand for food in Altamira's markets was expected to boost production in the local agropastoral economy. However, the supply of jobs during the dam construction to work in the dam or in the new jobs in the urban area led to an exodus of rural workers, causing a shortage of labor in rural areas and an increase in labor costs of the agricultural activities. This scenario has accelerated the trend of productive specialization of agricultural commodities (i.e., beef and cocoa) instead of strengthening the local agricultural production to supply the local markets with vegetables and staple crops. Labor shortage in rural areas was the main driver of changes in the local agricultural activities and the impacts were more evident among the households with lower purchasing power and less market integration. The study shows that the impacts of large dams on the agricultural sector tend to vary according to the degree of consolidation of the productive activities and the market conditions of the products associated to these activities at the time the changes occur (i.e., the period of the dam construction). The study shows that the promises made that the dam would lead to regional economic development were not delivered, and that the agricultural sector if anything declined in its food production capacity. Governments and dam builders should either not promise, or make better plans and policy making to ensure that these goals are achieved.

1. Introduction

The growth of population and consumption patterns increase demand for electricity (Gibson et al., 2017) pushing national governments to invest in electric generation to ensure the development of their countries. The growth of electric generation has driven increases in CO2 emissions to the atmosphere, mainly through the use of fossil fuels (Butt et al., 2013; Fearnside and Pueyo, 2012). Global electricity production reached around 25,518 TW h in 2017, with about 73.5 % from non-renewable sources (REN21, 2018). Over the last few decades, several countries have secured investments in electric generation plants using renewable sources (REN21, 2015; Yüksel, 2010), notably hydroelectric dams, which currently provide about 61.8 % of global renewable electricity (REN21, 2018). The installed capacity in hydroelectric dams increased mainly in countries with a low level of socioeconomic development (Chen et al., 2016), which resulted in the emergence of mega-dams around the world, such as in the Amazon, Congo and Mekong basins (Moran et al., 2018; Winemiller et al., 2016).

Since the 1960s Brazil has expanded its hydroelectric generation capacity based on the exploitation of its rich hydrological resources, that gives it a geopolitical strategic advantage based on the application of modern technology and resulting in large-scale socio-environmental transformations (Becker, 2016; Oliveira, 2018; Sneddon, 2015). By having a large hydrographic network, "hydroelectricity emerged as the

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https://doi.org/10.1016/j.landusepol.2019.104327
Received 19 May 2019; Received in revised form 13 September 2019; Accepted 22 October 2019
Available online 07 November 2019
0264-8377/

nation's 'natural vocation' and became one of the bastions of the Brazilian modern paradigm" (Fuchs, 2016, p. 227). This geopolitical model of development remains strong today. According to data from the Brazilian Government and energy sector, the country is planning to add around 2.8 GW/year of hydroelectricity until 2027 (MME and EPE, 2018), with Amazonia being the center pin for this expansion. The Amazon region, considered a hydroelectric development frontier (Jiang et al., 2018; Moretto et al., 2012), has estimated potential to produce 77 GW from water resources (Brasil, 2007), and has 352 planned dams, 96 of them "large" hydropower (> 30 MW) and 256 will be small ones (Aneel, 2019).

Although providing a reliable source of electricity, hydroelectric dams represent large investments - 42 billion reais in the case of Belo Monte (Brasil, 2019) that do not come without controversies in public opinion about their socio-ecological and economic impacts (Fearnside, 2004; Legese et al., 2018). This is aggravated further because comprehensive official assessments that help minimize the impacts that these megaprojects cause are rare, often constrained by the limited availability of information and/or conflicts of interest (Bro et al., 2018; Hanna et al., 2016). There is also a lack of academic research on the effects of these projects on the region where they are built. Studies examining impacts of hydroelectric dams on rural communities mostly address socioecological and economic impacts and the effects of the dams over the communities with livelihoods dependent on the river such as fishing communities, farmers downstream who cultivate on the floodplain enriched by sediment deposited during the rainy season, and riverbank communities (Bro et al., 2018). There is a lack of knowledge about how farming communities away from the dam itself and the river are impacted during the period of construction, when major political, economic and demographic changes occur in the region influenced by the mega-project (Moran, 2016). This is the first paper to directly address this question in the literature.

This paper will focus on these impacts to contribute to the literature on how hydropower dams affect a variety of stakeholder populations. We discuss how rural agricultural households have been affected by the development of a large dam, especially how it impacts the rural labor mobility dynamics and the effects on the agropastoral activities. We focus on the case of the Belo Monte Dam, described as the world's third-largest hydroelectric dam at the time of construction (2011–2019), but it is likely this occurs very often where there is a substantial agropastoral sector that would be affected by the loss of farm labor to construction and development in dam affected regions.

2. Hydroelectric dams and their consequent regional changes

Mega-dams induce changes that go beyond the scale of the territory where they are built (Bortoleto, 2001). These large constructions are installed in regions with low population density and low levels of socioeconomic development (Moran et al., 2018; Sneddon, 2015). Therefore, mega-dams promise to create regional economic growth through the creation of local jobs and investments. Dam supporters advocate the idea of "common good" and "national interest" as the reason to build dams (Pinto, 2012), Their discourses and support are based "on the promise of reducing regional inequalities, on the propaganda of an illusory internalization of growth" (Vainer and Araujo, 1992, p. 49), and the impacts from those projects are explained as the necessary “hidden” costs of development (Bortoleto, 2001; Pinto, 2012). In the search for popular support for mega-dams, improvements in infrastructure and local services are announced as a kind of legacy of these projects for the region where dams will be built. The expansion of electricity grids, roads and waterways (Lees et al., 2016), improvements in public health services, education and security (Marin and Oliveira, 2016) that will come are examples of potential benefits supporters use to justify the dam.

In reality, mega-dams are constructed to serve economic sectors and users outside the regions where they are located (Becker, 2005), to the detriment of people living close to the areas affected by the reservoir (Duflo and Pande, 2007; Maia et al., 2017; Moran et al., 2018). These projects commonly underestimate their social and environmental impacts and the financial costs, while systematically overestimating their benefits (Fearnside, 2005; Moran et al., 2018). Evidence suggests that the benefits produced by mega-dams have not surpassed their real financial costs, because a number of externalities are neglected or poorly evaluated by projects and their supporters (Ansar et al., 2014; Del Bene et al., 2018; Namy, 2007; Sevá Filho, 2008). The impacts are treated as "temporary", limiting the attention or mitigating measures during the period of the construction of the dam. Among the main impacts neglected by mega-dam projects are the changes in local social dynamics, especially those related to the migration flows and the demographic boom associated with labor mobility (Alves and Thomaz Júnior, 2012; Miranda Neto, 2016; Santos, 2007; Wood et al., 2011; Zhouri and Oliveira, 2007).

2.1. Mega-projects and labor mobility

Large infrastructure projects transform the landscape rapidly and require investment and coordinated actions at the State level and investments (Gellert and Lynch, 2003). The installation of large projects follows the logic of capitalist reproduction and its entrepreneurs use all the available strategies to maximize their profits, holding control of the factors of production, especially labor. Even with the use of modern technological equipment that result in high labor productivity, the installation of large projects (e.g., mega-dams) demands a significant human labor force. Usually, the labor requirement is greater than the labor available in the construction region, and a notable portion requires expertise not normally found in the region where dams are built. In this case, the mobilization of workers from one dam construction site to another is routine and is strategic to allow the execution of the projects (Becker, 2006; Alves and Thomaz Júnior, 2012).

Labor force mobility is a recurring theme addressed by the social sciences and is key to understanding how capitalism displaces population in order to amplify the reproduction of capital. The cycle of capital accumulation and its productive expansion is related to the exploitation of the labor force over the surplus population, composed by the mass of unemployed or underpaid workers from regions with substantial underemployed populations (e.g., farming areas dominated by large properties, metropolitan regions) and therefore apt to be absorbed in new movements of capital expansion (Miranda Neto, 2015, p. 2). Known as relative overpopulation, this group of people represents a surplus of workers, above the average needed for capital appreciation. This “relative overpopulation constitutes an available 'industrial reserve army', which absolutely belongs to the capital, as if it had created it at its own expense" (Marx, 1996, p. 191). "Capital can choose the labor force as it wishes and how it will be more profitable, because stocks of surplus population grow in a frightening way" (Becker, 2006, p. 334).

The reason why mobility exists in capitalism lies in the idea of the workforce’s free will (Miranda Neto, 2015). If the worker is "free" the work is mobile (Marx, 1996), which means being able to move and change his/her job. Thus, mobility is understood as the exercise of the worker's freedom to choose becoming a commodity, whose consumption will create value and thus reproduce capital (Gaudemar, 1977). The mobility of the labor force allows the worker to adapt (plasticity) to the needs of production, a necessary condition for the genesis of capital and an indication of its growth potential (Thomaz Junior, 2013). In this scenario, the capital needs are met with the migration process, not the needs of individuals (Gomes, 2009). Therefore, it is up to the workers to migrate or live relying on scarce resources in their regions of origin, sometimes subject to conditions of deprivation and subsistence (Miranda Neto, 2015).

The growing ‘industrial reserve army’ (Becker, 2006), means that there is a group of workers available and able to sell its labor force at any price, place, and conditions (Perpetua, 2013). This justifies the

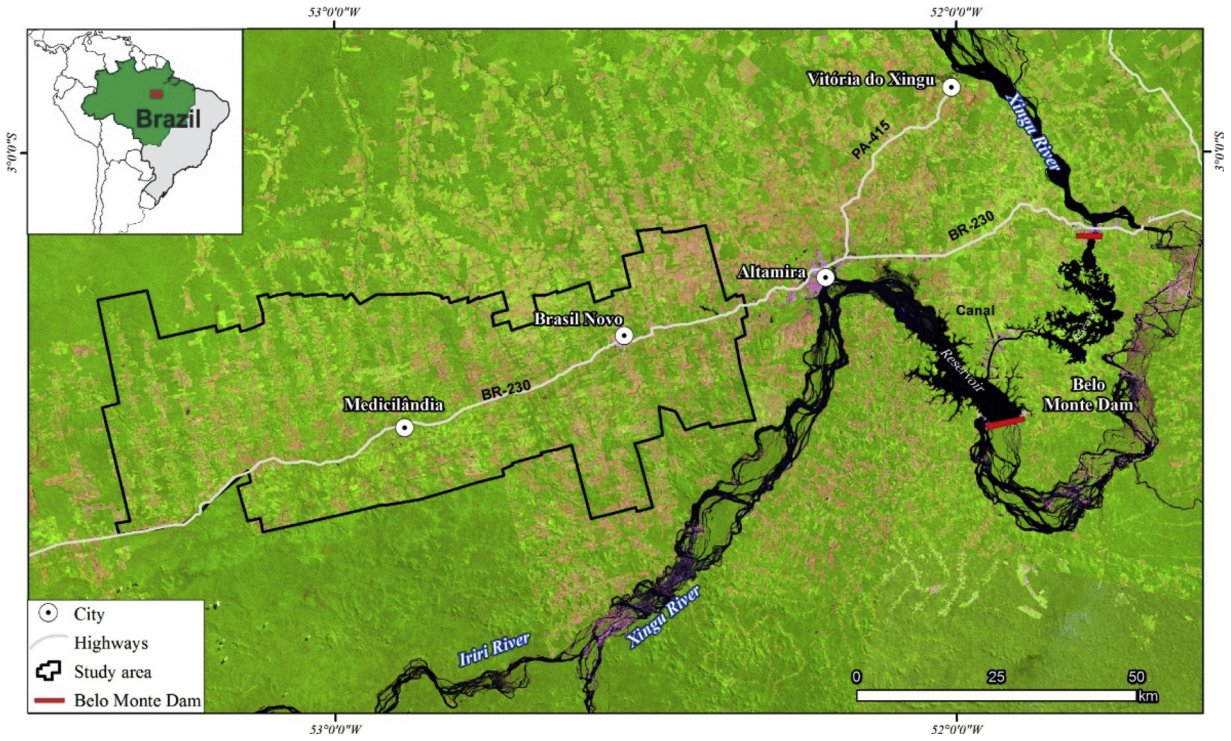

Fig. 1. Map of the study area and Belo Monte Dam region.

significant displacement of population towards large investment projects of infrastructure, as in large hydroelectric dams.

A significant part of the impacts promoted by the construction of mega-dams is the demographic in-flow to the construction site and surrounding areas. The capacity for labor mobilization in mega-dam projects triggers migration of workers from different parts of the country or from other nations, seeking to ensure social and family reproduction (Colson, 2003; Randell, 2016). Hydroelectric dam projects have always attracted migration flows greater than the effective capacity to absorb them, leading thousands of other workers to settle for a few years in the nearby cities working in local commerce or underpaid urban activities, where jobs might be available (Leturcq, 2019a; Miranda Neto, 2015).

This migration attracted by mega-dam construction has several faces: it mobilizes the labor force, which is a fundamental condition to make possible construction projects, triggers a demographic boom and brings about social disturbances, environmental and economic problems. These effects are aggravated in small cities where dams have been built in the Brazilian Amazon. Among the most emblematic cases is the Tucuruí dam, built in the eastern Amazon between 1975 and 1985, where the population in the small city of Tucuruí jumped from 10,901 to 182,021 (Rocha, 2008), a population increase of around 1,700 % in a decade.

Regardless of the scale of the projects of large infrastructure, problems associated with dam construction to increase energy supply have been observed worldwide and widely discussed by the scientific community (Ansar et al., 2014; Fearnside, 2016a; Lees et al., 2016; Legese et al., 2018; Nany, 2007). The planning and construction of mega-dams takes several years (more than 30 years passed since the first studies of Belo Monte dam until the beginning of its construction). However, governments and companies involved have not done enough to prevent or to mitigate the widely known impacts of dams. The changes in environmental legislation in Brazil since the 1990s has not yet proved capable of addressing known problems and still grants environmental licenses for mega-dams construction even when controversial social and environmental impacts are pointed out by environmental and social impact assessments (Bragagnolo et al., 2017; Fearnside, 2016b; Moran et al., 2018).

In an attempt to reduce impacts of intense migration to the construction region of Belo Monte Hydroelectric dam, especially in Altamira, the Environmental Impacts Assessment (EIA) for the construction and implementation of the dam brought an innovative mechanism – the alleged prioritization of hired labor from the local labor market (Eletrobras, 2009). However, it proved an inefficient mechanism as thousands of workers migrated to the region regardless of the prioritization of local labors. The mechanism presented in the EIA to license Belo Monte dam in fact favored local workers able to occupy new job openings. Various employment opportunities emerged not only for unemployed population, but also for employees of urban or rural activities that moved to the dam construction to pursue salary improvements. It is in this context of labor and employment in urban and rural spaces that Belo Monte dam construction transformed the productive and economic dynamics of the Altamira region. The demographic boom caused by the construction of Belo Monte enhanced employability in urban areas due to the economy blooming in consumption and services while in rural areas an intense displacement of rural workers to cities of the region was observed.

In the following sections, we will discuss the question of rural labor in the surrounding regions of Belo Monte hydroelectric dam (i.e., Altamira region), as well as the out-flows of rural workers during the construction of the dam and how this displacement of the workforce affected the regional agricultural sector.

3. Data and methods

3.1. Study area

The study area includes four municipalities located in the west of Altamira city, along the TransAmazon Highway, in the eastern Brazilian Amazon (Fig. 1). The Altamira region consists of eight municipalities, that gained national and international attention because of the construction of the Belo Monte hydroelectric dam, the largest infrastructure project of the Brazilian government in recent decades. It began in 2011 and the full installation of all 24 turbines is expected to be completed

sometime in 2019 (Feng et al., 2017). Because of this mega-project, all municipalities in the Altamira region are considered impacted by the dam, directly or indirectly. This region was colonized in the early 1970s, based on a major strategy of the Brazilian government to occupy the Amazon territory with roads and government directed settlement. The construction of rural settlements and extensive highways linking the Amazon to the other regions of Brazil, generated an intense migratory flow of farm families in search of land to work (Kohlhepp, 2002; Moran, 1981). As in other regions of the Amazon, an orthogonal land pattern of land settlements, with rectangular properties of 100 ha, distributed along roads perpendicular to the highway, in a scheme known as "fishbone" settlements was developed (Batistella and Moran, 2005). Agropastoral activities developed over the last four decades led to extensive deforestation in the region, producing landscapes that are increasingly fragmented (Batistella et al., 2003; Brondízio et al., 2009).

3.2. Data collection and analysis

This study is part of a large panel study, which uses longitudinal data of a fixed sample of 402 rural properties at various time intervals. The first field survey took place in 1997/98 and the second in 2005, focusing on the relationship between demographic structure and deforestation in the Amazon (McCracken et al., 2002). The third survey was conducted in 2015 and maintained a significant part of the scope of the previous surveys to ensure continuity of the longitudinal data and incorporated research on human impacts of the dams, focusing on the socioeconomic and environmental impacts caused by Belo Monte dam and its effects on the land use and land cover change in the Altamira region.

The definition of the study area and sample size was based on the identification of the pattern of farm occupation by the use of remote sensing tools (Moran et al., 2000) when identified that migrant farmers in this region deforested a minimum of 5 ha in the front of their properties in the early years of occupation. Deforestation of more than five hectares would be indicative of the beginning of agricultural activities by a household that had begun to occupy that property. Using remote sensing techniques, cohort definition maps were produced at farm level, which represented the migrant farmer groups and the years of arrival at the farms. A set of 10 images were used, covering the period from 1970 to 1996 (aerial photographs for 1970 and1978; and Landsat Multispectral Scanner-MSS for 1973, 1975, 1976, 1978 and 1979; and Landsat Thematic Mapper-TM for 1985, 1988, 1991 and 1996) (McCracken et al., 2002). The area is equivalent to 40,200 ha, with 3916 properties delimited according to the agrarian grid of the National Institute of Colonization and Agrarian Reform - INCRA. A stratified random sample by proportional cohort membership of 402 farms was defined to conduct in-depth interviews with households, their socioeconomic and demographic characteristics, their productive strategies and land use history. Detailed descriptions of the methods are described in Moran et al. (2000); Brondízio et al. (2002) and Brondízio (2005).

The 2015 survey was applied between the months of January and May conducted by a group of 17 researchers, subdivided into three field teams. Two questionnaires were used: the first one was applied to all the owners of rural properties or those who manage the properties, mainly addressing the productive strategies and economic aspects of land use and land cover. The second was applied to the family member responsible for domestic activities (usually the female head of household) to understand their demographic characteristics, family composition, and household characteristics. Both questionnaires sought to capture the perceptions of the respondents about the recent changes in the socioeconomic and political situation of the community and the region. The questionnaires were structured with open or multiple-choice questions, to better capture the information of the interviewees. An average of two households per day were interviewed by each researcher. For this article, we use only labor-related data at the community and household level.

The fieldwork data were divided into two categories of rural producers, “family farm” and “commercial farm”, for comparative analysis. In the scientific literature, "family farm" is defined by many interpretations given the diversity of social categories that they may represent (Caume, 1996; Gasson and Errington, 1993; Kasimis and Papadopoulos, 1997; Neves, 1995). For this study we used the Brazilian government’s definition, which mixes theoretical aspects established in the literature and normative elements attributed by legislation. Therefore, the "family farm" represents the agricultural establishments that have (a) the family taking the decisions to manage the property, (b) that uses predominantly the family's labor force in productive activities, and c) the size of the property is smaller than or equal to a regional standard (Brondízio et al., 2009; Guanziroli, 2001), established by National Institute for Colonization and Agrarian Reform (INCRA in Portuguese). For the study region, INCRA determined a maximum size of 300 ha to be considered a family farm. The "commercial farm" group represents the establishments in which agricultural production systems use predominantly hired workers and or rural properties larger than 300 ha. This group is composed mainly by medium and large farms or by small farms with family members having primary economic activities in urban centers (then the need to hire workers to keep the farm’s production systems). The definition of both groups in key for the study because there are different governmental public policies for each one (Paula Filho et al., 2016a, 2016b), which may influence the living standards in rural areas, productive and economic dynamics, and the trajectories of land use and land cover changes.

In addition to fieldwork data, census-based socioeconomic data from the Brazilian government provided by the Brazilian Institute of Geography and Statistics (IBGE in Portuguese) and the Ministry of Labor and Employment (MTE in Portuguese) were used in the study. Descriptive statistics were adopted to present the impacts of the Belo Monte dam perceived by farmers at the level of the region, community and rural households. Given the non-normality of the data, we needed to use non-parametric statistics, e. g. Kruskal-Wallis and Mann-Whitney tests, with a 95 % confidence interval.

4. Results

4.1. Belo Monte dam and impacts on rural labor

Since the 1990s, the formal labor market in the Altamira region had been in a stable trajectory, mainly composed by jobs in the sectors of commerce and services. For the agricultural sector, official employment numbers have historically been very uncertain, largely due to the many informal jobs activities in rural areas as compared to urban formal jobs. From the beginning of the Belo Monte dam construction, significant changes became evident in the dynamics of the labor market. Although the construction sector absorbed the largest contingent of workers, the demographic boom in Altamira city boosted the local economy, which led to a significant increase in the supply of employment in other economic sectors (industry, trade and services).

From the CAGED – a database of the Ministry of Labor and Employment (MTE, 2018), it was observed that the formal employment rates increased sharply between 2011 and 2013, and reached a peak in 2014, with 43,207 formal jobs, the highest number of new jobs in Altamira (Fig. 2A). Although the location of the dam construction, mainly in the municipality of Vitoria do Xingu, growth rates in the number of jobs was just observed in 2014 and 2015, with a peak in admissions of 4334 (Fig. 2 B). During this period, the CAGED data registered a reverse process in Altamira, with significant demobilization of labor, both in construction and in other sectors of the economy including the rural sector. This is as expected due to the ending of the major concrete placement stage creating the reservoir which demand a large number of workers, followed by the beginning of the turbine installation stage, which requires fewer but more specialized employees. In 2017, the

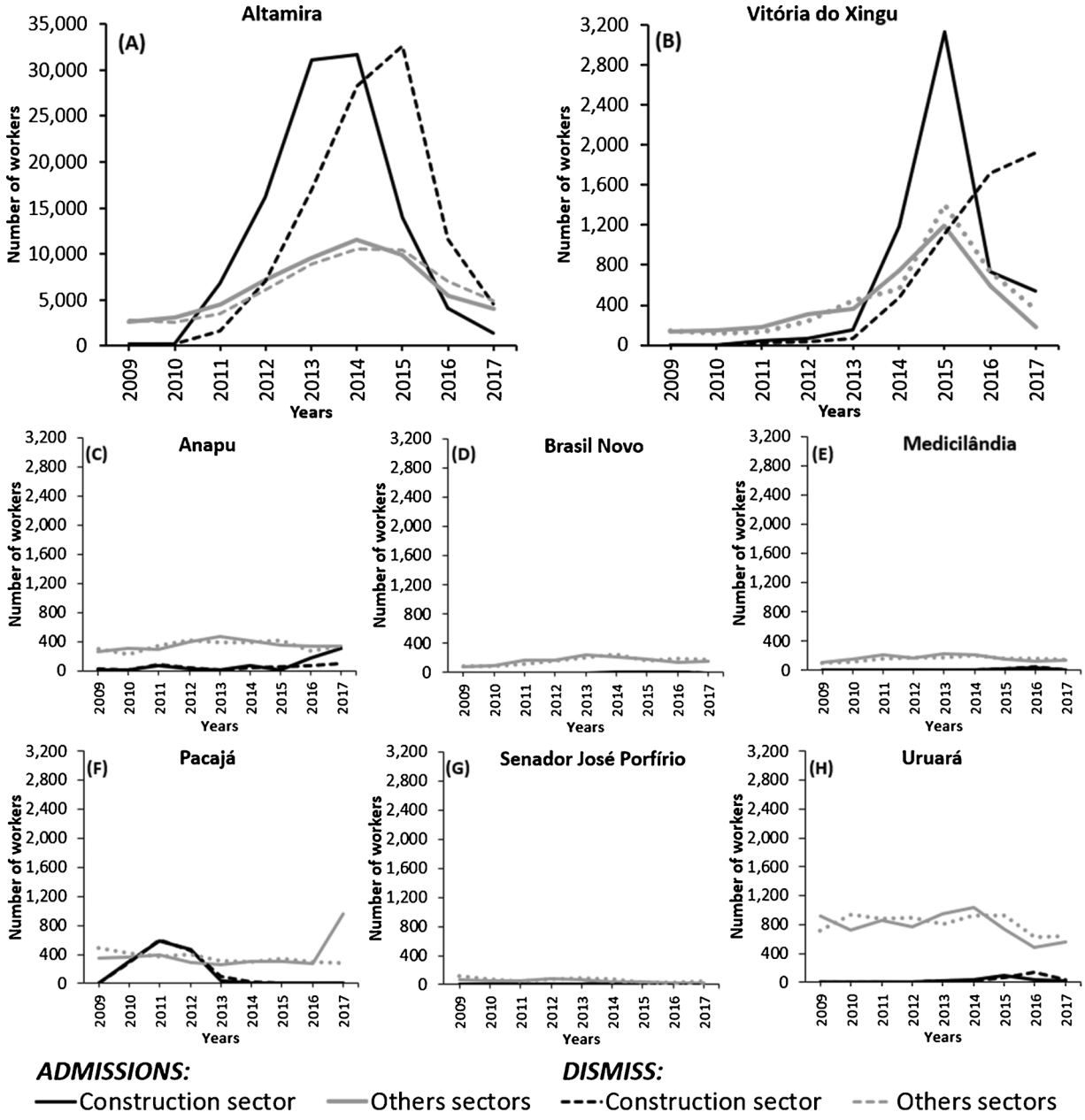

Fig. 2. Evolution of employment in the municipalities of the Altamira region during the construction of the Belo Monte Dam. Admissions and dismiss totals in the construction sector and comparison to other economy sectors (industry, trade, services and agriculture).
Note: Graphic representation for (A) and (B) at a different scale and (B) to (H) at same scale.
Source: CAGED database - Brazilian Ministry of Labor and Employment, 2018.

formal employment rates returned to the levels prior to Belo Monte dam in all economic sectors, mainly because of the ending of the dam construction. In other words, very little new formal jobs were created permanently by the dam. Despite the magnitude of the dam and its potential impact over the entire region, Fig. 2C–H shows that the increase in the number of jobs was not observed in other municipalities near the dam, and that the employment benefits were restricted to the immediate area where the dam was built. Only one municipality shows a slight increase in employment (see Fig. 2F), but in that case, it is not related to Belo Monte but to the construction of transmission lines to carry the energy from Tucuruí Dam to others states in North Brazilian.

The curve described in Fig. 2A (i.e., admissions or new hires) is in accordance with the Belo Monte Environment Impact Assessment (EIA), which described the first three years of the dam construction as the period of greater recruitment of workers (Eletrobras, 2009). However, the official data reveals a problem in the jobs created: a very high turnover of employees. The high turnover in employment is a common problem in the Brazilian labor market (Gonzaga, 1998; Ramos and Carneiro, 2002) and systemic in the case of large construction projects, which trigger intense migratory flows (Souza, 1988). During the period between 2011 and 2014, at the peak of the Belo Monte construction, CAGED data indicated that, on average, 76 % of civil construction admissions or hires had a maximum employment time of three months (MTE, 2018).

Analyzing work and employment dynamics in the construction of the Tucuruí dam, in Pará state, Souza (1988) found a higher level of turnover, where 20 thousand workers could be fully replaced in an interval of two months. According to Alves and Thomaz Júnior (2012, 2011), the high turnover rates of employments observed in the construction of large dams favors a scenario of degradation of living and

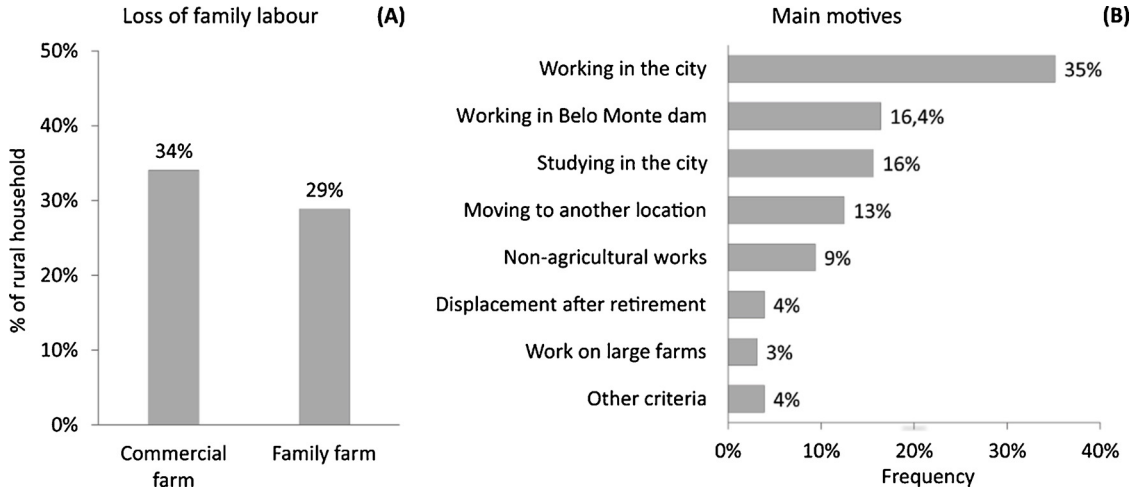

Fig. 3. Loss of family labor from households between 2010–2014 in the Altamira region (A) and the motives perceived by the farmers interviewed (B).

working conditions. This is due to the fact that migrant populations in the regions where large projects take place do not have many stable employment choices. Hence, workers take the employment opportunities that arise and companies exploit this abundance of labor as a way of minimizing benefits provided to workers.

As a strategy to mitigate the impacts of the migratory flow, the Belo Monte EIA established that 60–70% of the workforce absorbed by the dam construction should be from the Altamira region, however, such guidance was not sufficient to avoid large migration flows from different Brazilian regions. According to Miranda Neto (2015), the consortium that build the Belo Monte dam hired a total of 45,934 workers between 2011 and 2014, equivalent to 46 % of the Altamira population of 2010 (IBGE, 2017). For the author, the demographic boom of the regions of large dam constructions is related to the Brazilian socio-economic inequalities and the existence of a relative surplus population that "is taken as a reserve for the moments of the expansion of economic activity, as in the construction of large infrastructural projects or in the existence of industrial outbreaks." But when this surplus is not available in a given region, the territorial division of labor fulfills the demand, making it possible by mobilizing flows of workers dispensed from other regions, feeding the 'hydroelectric cycle' (Miranda Neto, 2016, p. 162). The applicability of this theoretical orientation is clearly perceptible when analyzing the flows of labor mobilized for the construction of Belo Monte. The workers absorbed by the construction of Belo Monte came from more than 1500 Brazilian municipalities (Miranda Neto, 2015), some of them from regions where other large dams were built. This is the case, for example, of the workers from Tucuruí city, Pará state, where the hydropower's navigation locks were concluded in 2011, and Porto Velho city, capital of Rondônia state, where the main concreting stage of the Jirau and Santo Antônio dams in the Madeira River were completed between 2011–2013.

Although Belo Monte dam construction has triggered a migratory flow of workers from different parts of the country, the number of workers from municipalities of the Altamira micro-region accounted for about 15,000, equivalent to 33 % of the total hiring by the dam construction up to 2014. These numbers represent a significant participation of the work force of the Altamira micro-region in the Belo Monte construction, but it is only one dimension of the effect of the migration of workers from the micro-region to the Altamira city. A significant portion of workers was absorbed indirectly by companies that provided services to the Belo Monte construction company and by local commerce and service sectors of Altamira.

The possibility of jobs, fixed wages and labor rights were the most important benefits expected by the different groups of migrants from various parts of the country to Altamira during the dam construction (Leturcq, 2019b; Miranda Neto, 2015). We observed from fieldwork that these motivations were the same to a significant portion of rural populations in Altamira region that led them to move from rural to urban areas. This phenomenon, perceived locally in different ways, represents the main reason for the increases in production costs of rural activities, reinforcing the effect of the dam construction to the rural economic dynamics. Later, we will analyze the behavior of the labor force in rural areas, the effects produced on the agricultural sector and how the local farmers perceive the effects.

4.2. Outflows of workers from rural areas

The issue of rural labor in the context of the construction of Belo Monte is more complex than simply pointing out the variation in the period or breaking down variables related to employment in rural areas. The perception of the rural workers outflow was widespread among the households studied and it produces effects that vary according to the type of production system (i.e., family farm or commercial farm), financial conditions of households or main economic and productive activities. Although the migration of people from rural areas to urban centers is not a recent phenomenon, the rural labor force migration became bigger in the agricultural sector during the first years of the Belo Monte construction. In the sample of 2015, 90 % stated that after the Belo Monte construction started, they observed a sharp decrease of workers in the rural communities, while 7 % did not observe changes and 3 % noted an increase.

However, when questioned about the individual loss in each rural establishment, at the household level, 34 % of the interviewed from commercial farms reported loss of family workers in contrast to 29 % in the family farms, between 2010 and 2014 (Fig. 3A). This means that 63 % of the sample ($n = 336$) verified loss of family members from the rural properties to the urban areas. According to this group (63 % of the sample), directly suffered loss of family members/ workers in their rural properties given the migrations to urban areas, the search for job opportunities represented an important cause to 35 % of them, the Belo Monte construction 16 % and another 16 % of the respondents answered that the desire of rural population to get an education as an important driver of outmigration from rural areas (Fig. 3 B). For all the different reasons that are driving rural migration, the city of Altamira represents the major receiving system. The motivations were mainly driven by economic aspects represented by the search for better job opportunities in the urban centers looking for formal jobs, better income (higher wages) and labor rights. This phenomenon was not exclusive to the landless class of rural workers, but also to a portion of landowners and their household members.

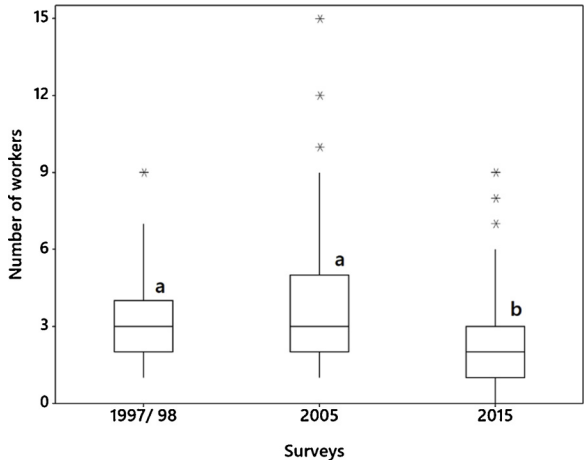

Fig. 4. Family labor in the farm sector in the region of Altamira along the three waves of the panel study.
Note: Different letters denote significant statistical differences between them (Mann-Whitney $p = 0.000$).

Comparing the longitudinal data collected in the three periods of the panel study (1997/98, 2005 and 2015), it is possible to visualize the changes in the number of workers in rural household along these decades (Fig. 4). The 2005 survey reveals a growth in the number of these workers compared to 1997/98, while the 2015 survey points to a decrease in the number of workers in rural households (Fig. 4). The statistical assessment indicates highly significant changes during the period studied (Kruskal-Wallis $p = 0.0001$), and the Mann-Whitney test shows significant differences between 1997/98–2015 and 2005–2015 ($p = 0.000$ respectively), but no significance between 1997/98 and 2005 ($p = 0.338$), i.e. the pre-dam period.

Regarding the access of workers to work in family farms or in commercial farms, the difficulty of hiring workers is higher for family farms than for commercial farms (Fig. 5A). Fig. 5A reveals that 90 % of the respondents from family farms had difficulty hiring employees, while only 69 % did among the commercial farms. According to 50 % of the interviewed group, the construction of Belo Monte lies among the major drivers to explain the difficulties of hiring employees in rural jobs. Another 17 % pointed out the lack of rural labor while 11 % believes that the increased costs of rural wage lies among the major reasons (Fig. 5B).

We investigated the number of workers employed by each rural household for the five years prior to field surveys, being the period of 2000–2004 for the survey of 2005, and the period 2010–2014 in the 2015 survey. Comparative analysis of the rate of hired workers during these periods show different trajectories over time. For the first period (2000–2004), highly significant annual differences were recorded among family and commercial farms ($p = 0.000$) (Fig. 6A). During the period of 2010–2014, there was a decrease of 50 % in the number of hired workers compared with 2005 survey data (Fig. 6B). Although farmers are emphatic in reporting their difficulties in hiring workers in rural areas during the construction of the Belo Monte dam, the average number of workers over time shows different changes according to the type of agricultural establishments (family or commercial farms) and in each year analyzed. For both types of agricultural establishments, there was a tiny decrease in the number of workers between 2010 and 2013, with changes in the trend in 2014. In 2014, a recovery was observed in the number of hired workers in commercial farms but a slight decrease in the number of hired workers by the family farms. The variations are statistically significant between family and commercial farms in each year analyzed (2010–2014), with family farms showing lower values than commercial farms ($p = 0.004$; 0.018; 0.018; 0.028, and 0.011, respectively). Although there are differences in each year, the evaluation for this period indicates no statistically significant differences ($p = 0.716$, in Figure B).

The agricultural production systems of Altamira region are characterized by a low level of mechanization and technology adoption (Calvi et al., 2010). This characteristic makes the agricultural activities highly dependent on the contribution of human labor. As a result, the rural households with a large number of family workers have productive and economic advantages compared to households with only a few workers. Therefore, the maintenance of the domestic units' socioeconomic living standards depends on a sufficient amount of family workers, or in the absence of this asset, they will rely on their financial capacity to hire employees and to manage the farm (Chayanov, 1986).

The loss of rural workers observed in the last two surveys (2005 and 2015), reveals the complexity of the problem caused by the scarcity of rural labor, as stated by the different answers from the social actors affected by it. In the case of the Altamira region, this scenario produced rural wage inflation, which increased the production costs of rural activities, mainly perceived by family farms, and may also be due to the small-scale land area of their rural establishments, lower levels of market integration and the productive model of family subsistence. This phenomenon was largely observed in the properties where the labor force was predominantly dedicated to the cultivation of staple foods. The impacts of labor costs also affected family and commercial farms, which at the time had financial limitations, even for the ones producing cocoa and cattle, the most consolidated agricultural activities of the Altamira micro-region. This scenario has triggered land use changes

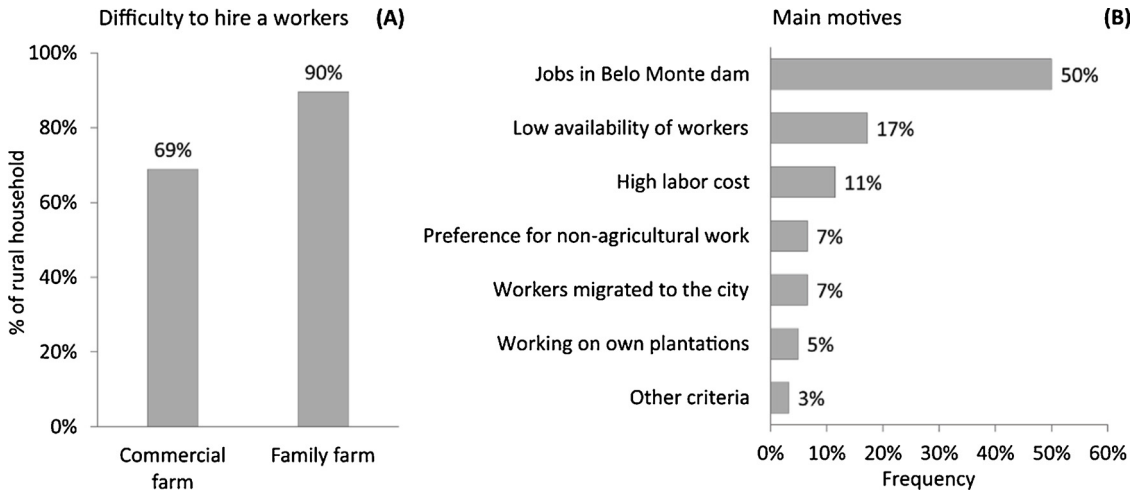

Fig. 5. Conditions influencing access to labor (A) and the perceived motives with regards to obtaining hired labor (B).

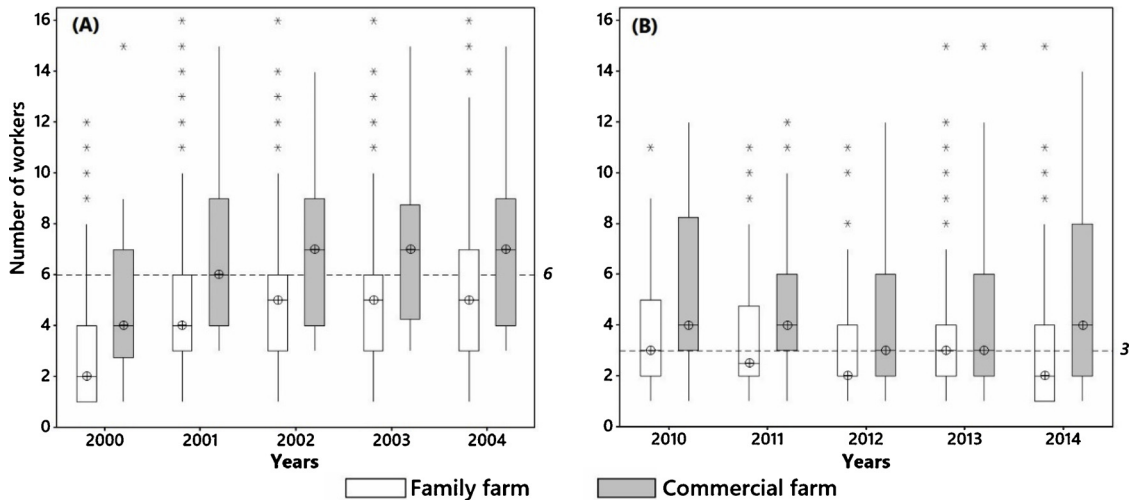

Fig. 6. Outside labor hired by the farm sector in the region of Altamira, (A) refers to the 2005 survey and (B) to the 2015 survey.
Note: Kurskal-Wallis, $p = 0.000$ for (A); and $p = 0.716$ for (B).

because households with financial limitations had totally or partially abandoned their plantations, and they had to seek other sources of farm or non-farm income.

The analysis of the average values of the daily wage paid to rural workers, during the initial years of the Belo Monte construction (between 2011–2014), highlights key elements of the problem of rural labor scarcity. Fig. 7 and Table 1 show an upward trajectory during the period with significant statistical differences for the comparisons (annually) between 2011 and 2014 (Mann-Whitney $p = 0.000$), as well as for the entire period (Kruskall-Wallis $p = 0.000$). The data indicate that in the first two years of construction of the dam there were significant statistical differences regarding the wage values paid by family and commercial farms to rural employees. The commercial farms paid, on average, 12 % more than family farms (Kruskall-Wallis $p = 0.043$ and 0.016 for 2011 and 2012 respectively). From the third year of the Belo Monte construction (i.e. 2013), the problems associated to the rural workers scarcity and the increases in rural wages (i.e., increasing the

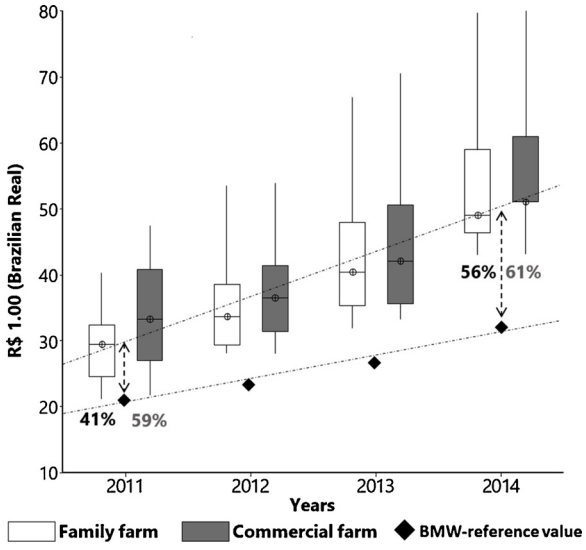

Fig. 7. Values paid for daily wage, by type of farm operation in Altamira, compared to the minimum wage paid at national level, as a reference.
Notes: BMW = Brazilian Minimum Wage; Comparison year to year are statistically significant (Mann-Whitney $p = 0000$). Significant comparisons between categories Family farm and Commercial farm for 2011 and 2012 and not significant for 2013 and 2014 were observed (Kruskall-Wallis $p = 0043$; $p = 0016$; $p = 0078$; $p = 0374$ respectively). See Table 1 for more detail.

Table 1
Median values for daily wage paid to rural workers in Altamira compared to the mean Brazilian minimum wage.

Description	Years			
	2011	2012	2013	2014
Reference value[1]				
BMW - Daily wage (R$)	20.85	22.97	26.50	31.80
Family farm[2]				
Daily wage (R$)	29.46	33.35	40.28	49.58
Comparison BMW (%)[3]	41%	45%	52%	56%
Commercial farm[2]				
Daily wage (R$)	33.20	36.87	43.09	51.15
Comparison BMW (%)[3]	59%	61%	63%	61%

Notes (Fig. 7 and Table 1): [(1)] Value calculated of the Brazilian Minimum Wage (BMW) based on the mean 21.2 working days in a month. Values for the BMW for each year 2010 = R$510, 2011 = R$545, 2012 = R$622; 2013 = R$678 and 2014 = R$724. [(2)] Field work data. [(3)] Variation calculated with reference to the BMW of the previous year.

production costs of rural activities) become more evident. The increasing trajectory of rural wages broadened the disparity compared to the Brazilian minimum wage (BMW) (i.e., lower than the rural wages), with stronger effects on family farms given the higher appreciation of the rural wage in family farms over the BMW, in 2014 (Fig. 7). The average daily wage paid by the commercial farms in 2011 was R$33.20 (Brazilian Real) or 59 % higher than the BMW for the same year, and R $51.15 in 2014 (61 % higher than the BMW). On the other hand, for family farms, the variation was higher in same period, from R$29.46 in 2011 (41 % higher than the BMW) to R$49.58 in 2014 (56% higher than the BMW) (Fig. 7 and Table 1). The appreciation of the commercial farm's wage over the BMW was 2 % in 2014 while 15 % in the case of the family farms, an increase of 13 % higher for family farms compared to commercial farms. The statistical test of Kruskall-Wallis shows no significant statistical difference between family and commercial farms in the average wages paid in 2013 and 2014 ($p = 0.078$ and 0.374, respectively).

The effects of the increase in rural wages and the consequent increase in the cost of living in the Altamira region reflected significantly on the cocoa sharecroppers group. The sharecroppers are agricultural partners of landowners who, instead of salary, usually earn a portion of the harvested revenue in the landowner's area. As the sharecropper's work regime is different (i.e. a partner, not an employee) they have greater autonomy to define their own working hours. Normally, in the study region, sharecroppers grow the cocoa plantations, have houses

and families in the landowner's area, and have greater stability in their occupations. That is, an opposite logic to that of 'day laborers', whose occupations are usually temporary, under verbal contracts, and subjected to intensive workdays by the landowner. Even with these characteristics, many of these sharecroppers also ended up leaving their crops to work in the Belo Monte dam (Alves Júnior, 2013) or migrating to urban areas. In order to avoid significant losses of these partners, many family and commercial farms increased the sharecropper's portion in the annual harvest, averaging an increase of between 10 % and 15 %, to stimulate them to stay working in the cocoa plantations.

5. Discussion

The labor scarcity phenomenon of the rural areas of the Altamira region reflects a set of different causes. First, the IBGE census data for the years of 1991, 2000 and 2010, prior to Belo Monte construction, noted a trend of decreasing rural population at an average of 7 % per decade, while the urban population increased 57 % in the same period (IBGE, 2017). These population trends hide some effects of the rural outmigration flows, since a large portion of urban residents without rural properties contribute their labor activities in the rural areas. There is also a growing number of landowners who have moved their residences to urban centers, seeking better housing conditions, access to education and health services or extra income in non-agricultural activities and who commute to their rural properties (Calvi et al., 2013). This is particularly important in the study region because of the scarcity of basic public services in rural communities, lack of support for local entrepreneurship, and the precarious traffic conditions of rural roads (Brondízio et al., 2009), especially during the rainy season. The 2015 survey confirmed the trend and showed an increase from 7 % in 2005 to 18 % in 2015 in the number of landowners living in urban areas but keeping their rural lands in use.

The second cause is the consolidation and expansion of cattle and cacao production, the two major agricultural economic activities of the Altamira region. The cattle herd increased 44 %, from 1.84 million animals in 2004 to 2.66 million in 2014 (IBGE, 2017), influenced by an increase of 80 % in the price of cattle in the international market in the same period (average of USD 84 in 2004 and USD 151 in 2014 per cattle *arroba* – a weight unit of measurement used in Brazil that is equivalent to approximately 15 kg (ESALQ/BM&FBOVESPA, 2017). The cocoa harvested area increased 150 %, from 29 thousand hectares areas in 2004 to 74 thousand hectares in 2014 (IBGE, 2017). Similarly, the cocoa plantation may also have been influenced by an increase of 99 % in the international Market price in the same period (average price per ton USD 1525 in 2004 an USD 3034 in 2014) (Investing.com, 2017).

The expansion of these agricultural economic activities drove the increase of rural workers in regular and temporary jobs in rural areas. Silva (2011; 2010), estimate the need of one worker to take care of 300 head of cattle in the Brazilian livestock sector. Therefore, we estimate a growth rate in the number of workers in the livestock (i.e., cattle) sector of 24 % between 2010 and 2014 (Fig. 8A). For the cocoa production system, a rural activity highly dependent on labor, the estimates of the Executive Committee of Cocoa Production (CEPLAC in Portuguese) for the Amazon region is the need of one worker for each 2.5 ha of cultivated cocoa land, on average - from the third year of the cocoa plantation onwards (Reis et al., 2002). Based on this rationale, we found a 70 % growth in rural workers to supply the labor for the cocoa production system between 2010 and 2014 (Fig. 8B). Therefore, the cattle and cocoa agricultural activities accounted for approximately 13,927 new jobs in the rural areas of the Altamira region.

The data shows that at the same time that the study region presented losses in rural population, it experienced significant expansion of agricultural activities. It therefore pushes the dispersion of the available labor force in the field to these new production areas implemented until 2014. Given the present scenario, the Belo Monte project has exerted strong influence in the complexity of the rural labor dynamics of the Altamira region. Belo Monte construction competed directly for workers in the region, who pursued better economic opportunities. The local workers are less costly to the companies taking care of the Belo Monte construction since it reduces the costs of installation of a larger number of migrant workers (from other distant Brazilian regions), as well as the expenses with transport to bring these workers from far regions.

This scenario also creates concern about the temporal extension of the socioeconomic impacts caused by the labor scarcity in the rural areas, as highlighted during an interview:

> "It is difficult to imagine what one might expect in the future of wages in rural areas in the region. However, one thing I am quite sure about: many workers who have left their rural communities to work in the dam construction, earning up to three times the Brazilian minimum wage, with formal contracts, and benefits such as food and health insurance, probably will not come back to rural areas searching for jobs paying a daily wage of R$ 50 to R$ 60" (J.P. Rural producer and union member, 52 years old, Altamira city - Free translation)

It is reasonable to assume that some of these workers of the Belo Monte project will return to rural areas, either because of their cultural identities with the rural lifestyle, family bonds, or even because of a lack of employment opportunities in Altamira after the end of the Belo Monte construction boom. The continued expansion of cattle and cocoa if it continues could absorb a significant proportion of rural labor. Others will remain in urban areas and will compete for jobs with those migrants who settled in the region, which according to the Environmental Impact Assessment-EIA of Belo Monte, was estimated might be as many as 29 thousand people. Another part of the rural migrant workers might build a new cultural identity as "barrageiros" (dam builders) (França, 2007) and join the migratory pathway that follows large infrastructural projects from one dam to another (Ribeiro, 1991).

From the history of hydroelectric power plants in Brazil, it is clear that this type of mega-project is different from other industrial sectors (e.g., automotive, telecommunications) given its capacity to absorb labor for a limited time period of about 5 years (Alves and Thomaz Júnior, 2012; Miranda Neto, 2015) and to change the regional political and socioeconomic dynamics. It is known that it is not the technical project of construction of the hydroelectric dam per se, which drives the major changes in the rural and urban communities, but the social processes intrinsically related to the construction, which includes the installation of a set of support infrastructure and mitigation works over a wide geographical area (Miranda Neto, 2015 p. 16). From this case study of the Belo Monte dam in Altamira, Amazon, we learn that mega-projects have greater pervasive effects, which go beyond what the specialists (e.g., government authorities, company representatives) define as the influence zones (Leturcq, 2019a). Neglected by public authorities are the lack of a rural economic development plan for the region that prepares the area for the impacts to come, before Belo Monte construction starts (Moran, 2016). In the case of the agricultural sector much could have been done to inform small and commercial farmers of the opportunities that they would have to grow by meeting the demand for food from some 50–70,000 more people coming to the region to build the dam. This would have required not only informing farmers, but providing short term farm credit to expand production of annual food crops, and preferential treatment given to this local production (just as the project favored hiring local labor), and ensuring that such produce could reach the consumers in the area. Measures could also be taken to reduce the negative impacts of inflated wages and loss of labor by providing incentives to invest in technology to increase productivity of the farm sector. Beyond the conclusions that we can capture about the case study region, our results shed light on major process of human intervention in nature through the construction of mega-projects.

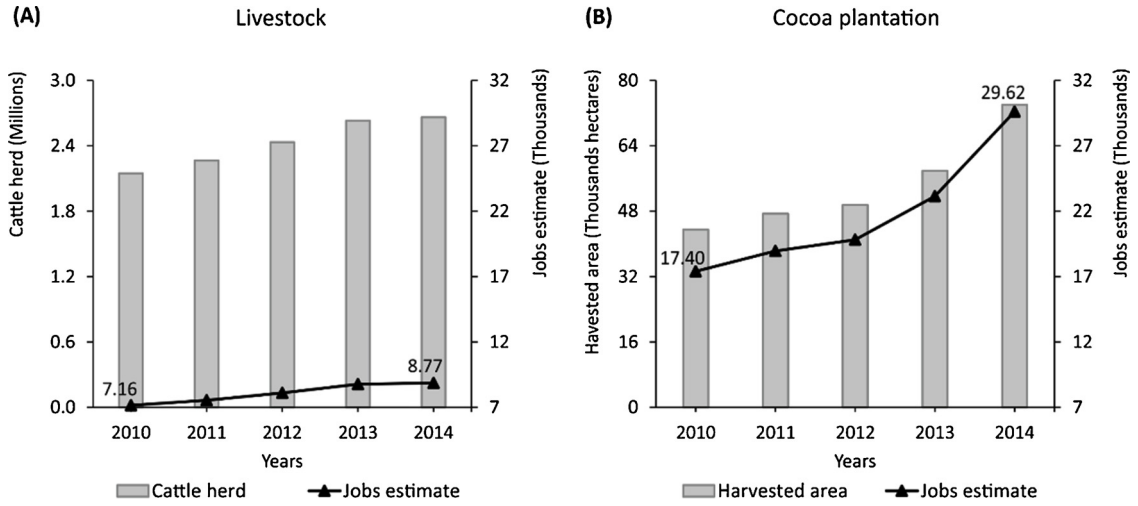

Fig. 8. Estimate of the Jobs generated by the cattle (A) and cocoa (B) production system in Altamira region between 2010 and 2014.
Notes: Estimate based on the data of the cattle herd and area of cacao harvested (IBGE, 2017). Graphic representation for "Estimated jobs" at same scale.

Mega-project construction projects have a great capacity to change landscapes and socioecological systems (Bortoleto, 2001), which is potentially dangerous in developing regions where the governance capacity to enforce legal rulings is weak (Fuchs, 2015), and where plans to anticipate potentially undesirable effects are neglected (Moran, 2016; Pulice et al., 2019; Sgarbi et al., 2019). The region of Belo Monte lost a great opportunity to develop its agropastoral sector by harnessing the money flows brought by the dam construction - 42 billion reais (Brasil, 2019) by directing farmers to meet the demand for food created by the inflow of population, and, instead, it is now a national leader in homicides, faces water and sanitation crises rather than improvements in these services, and has a public health system, overwhelmed by a lack of preparation (Calvi, 2019). In short, rural producers are being forced to adapt to a scenario of higher agricultural production costs and an uncertain future. Land use policies could have been designed in advance of dam construction to prepare farmers to capture the benefits of population growth, to improve use of technology in the farm sector thereby increasing productivity and reduce the limitations posed by the rising wages that should have been predicted by the arrival of a large dam, and bring about lasting economic developing after the dam construction is completed.

6. Conclusions

The construction of Belo Monte dam promoted an intense mobilization of workers and caused a demographic boom in Altamira region, Pará State. An important part of the workforce available in rural areas was directly mobilized to build the dam or drawn to commercial activities and services in urban areas. This situation led to a labor shortage pushing production costs in rural areas, which affected the entire agricultural sector of the Altamira region. Rural establishments with lower financial capacity and low available family labor were the most affected. Some rural households reduced their management practices or areas of crop production and pastures, others abandoned food crop production. Staple food crops (i.e. rice, beans, cassava, maize) were the main crops abandoned in the period of demographic boom, precisely the same period of great demand for food.

We found that the impacts of mega-dam construction on the agricultural sector varied according to the degree of consolidation of the region's productive activities and the market conditions of these products during the construction period. The Belo Monte construction occurred during a period of commodities' price appreciation (i.e. livestock and cocoa), which may mitigated part of the economic impacts of the dam in the Altamira region. However, the economic situation of the Altamira region previous to the Belo Monte dam construction may not serve as a baseline scenario for other regions in the Brazilian Amazon. Planned mega-dams in other regions (the regions of the rivers Tapajós, Aripuanã, Jari, Paru, etc.) with unconsolidated agricultural frontiers, highly preserved natural vegetation, may lead to even higher impacts than those observed in the Altamira region. This would suggest that even more anticipatory land use policies need to be put in place in these other planned dams go forward with construction. Dams could lead to a stronger farm sector, but to date they have not due to a lack of land use planning to convert these large projects as a source of stimulus to increase food production, and achieve local sustainable and lasting economic development.

As we have seen in another study (Bro et al., 2018), some positive changes occurred in the Altamira region, especially in infrastructure such as temporary improvements in the quality of roads, previously unpaved and impassable in the rainy season. Although positive, these changes are not enough to leverage the development of the agricultural sector, as advocated by the propagandists and pro-Belo Monte promises made. The reality of the rural areas of the Altamira region could have been quite different if governments and companies had implemented a strong program of anticipatory actions to address the inevitable and sometimes negative changes that occur when large capital infusion and large population inflows come as a result of the construction of a project like Belo Monte dam. It was a lost opportunity to achieve regional economic development.

Author contributions

M.F.C. and E.M. oversaw instrument design and data collection activities. M.F.C. analyzed data and wrote the paper with significant contributions from E.M., R.B.S. and M.B.

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgments

The authors acknowledge the support of the National Institutes of Health for the 1998 and 2005 panel study (97-01386A, which included three waves of funding between 1997 and 2012, two of them in this study area in 1997/8 and 2005); and from Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP for the 2015 panel study (process 2012/51465-0); and from Conselho Nacional de

Desenvolvimento Científico e Tecnológico – CNPq (process 409936/2013-8). M.F.C. is grateful to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES for the doctoral scholarship (processes 1531035 and 1442922) and the Fundação Amazônia Paraense de Amparo à Pesquisa - FAPESPA (ICAAF 004/2016). The authors are grateful to Professor Fábio Leão for his support in the statistical analysis; to Alexandre Augusto Lobato for his support in remote sensing and map production; and to two anonymous reviewers for important comments and propositions about the article. The views presented are the sole responsibility of the authors. No funds were received to cover the costs to publish in open access.

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