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Research

"Cities in the forest" and "cities of the forest": an environmental Kuznets curve (EKC) spatial approach to analyzing the urbanization-deforestation relationship in a Brazilian Amazon state

Renata Maciel Ribeiro [1], *Silvana Amaral* [1], *Antônio Miguel Vieira Monteiro* [1] *and* *Ana Paula Dal'Asta* [1]

ABSTRACT. Contemporary urbanization has been reorganizing the territories and the socioeconomic relations in the Brazilian Amazon as a whole. We seek to identify a general typology of relationships between urbanization and deforestation in the Brazilian Amazon, in the light of the environmental Kuznets curve (EKC) theory. We have applied this approach to the 144 municipalities of Pará, in the Brazilian Amazon, in the inter-census interval from 2000 to 2010. The EKC approach included the spatial analysis method of geographically weighted regressions (GWR). Deforestation, measured by the PRODES program by Instituto Nacional de Pesquisas Espaciais (INPE), was used as a measure of environmental degradation and the urbanization has been restricted to a socioeconomic characterizing, based on a set of 22 variables from the national census database, aggregated at the municipalities level. The results showed two main typologies: (1) the decreasing monotonic and (2) "U" shape. The first one indicates municipalities with urban-based economies that have in their income composition an important share of an economy based on the historical structural diversity of the Amazon rural production systems. The second one indicates municipalities with urban-based economies in which the income composition points to an agrarian economy based on rural production systems supported by large, intensified, and homogeneous landscapes that have established a predatory relationship with natural resources. We argue that these two typologies found can be used to establish two city models: "cities of the forest," where it would be possible to combine the local traditional knowledge with scientific and technological advances, mediated by the city life, and "cities in the forest," where the urban-industrial development strategy that has been changing the relationship between society and nature since the 1950s is in place and still very much alive.

Key Words: *Brazilian Amazon; environmental Kuznets curve; spatial analyses; urbanization-deforestation relationship*

INTRODUCTION

The different ways in which economic development influences the environmental characteristics of a given location have been discussed both by the bias of the impact of the evolution of the economy on the environment (Grossmasn and Krueger 1991, 1995, Caviglia-Harris et al. 2009, Oliveira et al. 2011, Tritsch and Arvor 2016, Luo et al. 2017, Tsiantikoudis et al. 2019, Santiago and do Couto 2020, Yasin et al. 2020) and by the bias of the limitations imposed by the environment for economic development (Forster 1973, Gruver 1976). For the Amazon region, the evidence that there are different patterns of relationships between deforestation and the socioeconomic development profile (Margulis 2003, Prates 2008, Rodrigues et al. 2009, Andersen and Reis 2015, Caviglia-Harris et al. 2016, Tritsch and Arvor 2016, Sathler et al. 2018) arouses interest to explore and describe this relationship. Understanding the possible connections between different development pathways and deforestation patterns is particularly important when highlighting models that start from a regional perspective and prioritize the territorialities and the preservation of the resources in a forest biome.

The environmental Kuznets curve (EKC) stands out as one initiative to explore the influence of economics on environmental outcomes. Described for the first time in the early 1990s (Grossman and Krueger 1991), EKC is algebraically represented in an econometric model that aims to identify theoretically predicted relationships between economic development and environmental degradation (Grossman and Krueger 1991, 1995, Shafik and Bandyopadhyay 1992, Selden and Song 1994). In short, developing regions, in which economic activities rely on predatory exploitation of natural resources, are prone to obtaining environmental degradation as a response. However, as the region improves its overall socioeconomic conditions and rethinks its technological patterns, combined with law enforcement, economic and environmental policies, the relationship between the variables changes and the economic pressure on natural resources tends to decrease. Therefore, EKC theory corresponds to this evolutionary process and characterizes the trajectory of environmental impacts, usually taking per capita income as an economic development indicator.

In this context, EKC has been used considering several environmental indicators, different sets of complementary variables, and space-time cutouts. Grossman and Krueger (1991), precursors to EKC, explored the relationships between air quality indicators and economic development to show the influence of changes in trade barriers on environmental aspects. They observed that the levels of two main pollutants (sulfur dioxide and smoke) increased with income in countries with low levels of gross domestic product (GDP) per capita and tended to decrease in countries with a more consolidated economy and higher GDP values. In 1995, the same authors studied the possible relationships between economic development, analyzed from the GDP per capita values and a composite variable of environmental quality, covering analyses of air and water pollution in 42 countries in different regions of the globe. The authors showed that, for most environmental indicators, the result of the EKC

[1]Instituto Nacional de Pesquisas Espaciais

model was established in an inverted “U” shape, presenting an initial phase of economic growth conciliated with increased pollution, followed by a phase of pollution reduction.

In the Brazilian context, Santiago and do Couto (2020) sought to analyze the relationship between deforestation and socioeconomic development for municipalities and observed the existence of a strong relationship between socioeconomic development and the use of forest resources, indicating the possibility of an inverted “U” shape relationship for this territory and analysis unit. However, the authors highlighted the existence of other factors responsible for deforestation, such as the effect of economic policies, legislation, and cultural aspects. For the Amazon region, Tritsch and Arvor (2016) observed the relationship between socioeconomic development and deforestation and confirmed the original hypothesis of an inverted “U”, emphasizing the precarious socioeconomic situation of areas still with active deforestation.

Eventually, when investigating EKC relationships, one must consider the spatial heterogeneity of variables. Using geographically weighted regressions (GWR), Tanaka and Matsuoka (2007) investigated the relationship between variables of socioeconomic development and pollution from industrial sources. The GWR method was able to respond with better adjustments in the model, concluding on the importance of considering spatial heterogeneity in the analysis of variables of a socioeconomic and environmental nature. Adopting a similar proposal, Oliveira et al. (2011) used the GWR method to investigate the relationship between deforestation and economic development in the Amazon in light of the EKC. Their results showed different relationships between deforestation and municipal GDP per capita, as well as different relationships between deforestation and other explanatory variables, confirming the hypothesis of variability for the modeled phenomena. Likewise, Kim et al. (2018) confirmed the inverted “U” shape for some regions in 22 provinces of China, testing EKC’s original relationship for economic development, mediated by income, and the emissions of three industrial pollutants (SO_2, residual water, and solid waste).

The EKC approach is also useful for exploring the process of urbanization and its environmental relationships. At a global level, Katircioğlu and Katircioğlu (2018) included dimensions of the urbanization process in the econometric model. They explored the relationship of carbon dioxide (CO_2) emissions in the function of economic development, energy consumption, and urban growth, understood as the evolution of the population living in urban areas. Environmental Kuznets curve’s relationship to urban growth and CO_2 emissions occurs in a decreasing monotonic shape, proving that the population concentration in urban areas, by itself, is not a decisive factor for the increase in greenhouse gas emissions. In the same way, Yasin et al. (2020) analyzed the impact of financial development, increase of urban population, commercial opening, presence of political institutions, and energy consumption in the ecological footprint of 110 countries. The authors confirmed the original hypothesis of EKC and observed the reduction of the ecological footprint with the increase in urbanization, reinforcing its positive environmental effect.

Despite its numerous applications, it is recognized that there are criticisms and limitations associated with the EKC conceptual-methodological proposal. As described by Stern et al. (1996), a limiting issue of this concept is to only consider the unilateral interaction of the effects of the economy on the environment. Environmental feedback, i.e., how the quality of the environment affects the economy, is not considered. In addition, the methodological assumption that income follows a normal distribution is also highlighted, which rarely applies to the units of analysis explored in research on this theme. The consequence being that these studies can estimate an average level of income, from which environmental degradation starts to decrease, which is not representative of reality (Kaika and Zervas 2013). Still, Stern et al. (1996) also discuss the limitations regarding the availability, regularity, and quality of environmental data, without which different results are generated for related studies. In addition to these technical and specific issues, there are limitations and disagreements associated with the EKC’s general hypothesis. In the current economic model, based on industrial capitalism, the perspective of continuous economic growth demands crescent exploitation of natural resources. This perspective conflicts with the proposal of environmental degradation reduction. Thereafter, ceasing the exploitation of natural resources or adopting sustainable production methods, in the first instance, would have an impact on economic growth. Thus, it is necessary to be cautious in interpreting the results, considering the limitations imposed by the conceptual model itself and the semantics and construction of the input data representing the analyzed processes.

In the Brazilian Amazon, an area of tropical forest with approximately five million km² where more than 70% of the population resides in officially urban areas (IBGE 2010*a*), to understand the urbanization-nature relationship we must consider that the presence and interaction with new agricultural and industrial activities have reorganized the space, historically, in its structure and socioeconomic relations. In the region, even today, the process of genesis and evolution of urban space is centered on cities and depends on urban-industrial dynamics. This urbanization replicates production systems exogenous to the Amazon, whose economic and behavioral patterns extend beyond cities. Spreading throughout the territory, these patterns overlap all the other human settlement logics immersed in the biome as a whole (Monte-Mór 1994, Lefebvre 1999). Additionally, the regional Amazon economy, which flows around the entire territory of the municipalities, is mediated by the cities and has, in this sense, an important extended urban base (Becker 2013).

The historical-geographic context of the occupation of the Amazonian territory highlights the importance of understanding the urbanization process to discuss the influence of human settlements on deforestation projections and, consequently, in the resumption of a development logic based on endogeneity, with the final objective being that of preserving the forest and the socio-cultural expressions of people who live in it. In this sense, Ribeiro et al. (2018) demonstrated that interactions between the evolution of urbanization and deforestation are not straightforward in the Brazilian Amazon. There are several agents and factors present in the territory, acting at different levels and scales, that indirectly influence deforestation and urbanization. This result points out that there are complexities and heterogeneities underlying the processes analyzed. Other studies help support these findings and show that urbanization has been seen as a process resulting from socioeconomic factors, and it is related to the evolution of deforestation in different ways (Molotch 1976, Becker 2013, Cardoso and Negrão 2013, Richards and Vanwey 2015, Tritsch and Torneau 2016).

Cities, as spaces for action and articulation between public and private agents (Moloth 1976), play an important role both in the occupation process of the territory as well as in the evolution of the regional socioeconomic development profile (Jacobs 1969). To understand the influence of different socioeconomic development profiles on environmental aspects inside the Amazon Forest biome, we no longer should think about "cities in the forest" (Castro 2009). But rather, we should go back to the idea of "cities of the forest", which was defined, in these terms, first by Browder and Godfrey (2006) and reinterpreted by Becker and Stenner (2008). For the latter authors, the "cities of the forest" are an alternative that combines traditional knowledge and technologies with new scientific and technical advances, looking for alternatives for development, capable of promoting the environmental responsibilities related to the use of forest resources. Cities are the settlements that are the basis for action, and they can take advantage of this potential for a harmonious relationship between economic development strategies and traditional knowledge of the native population.

We seek to identify the relationship between urbanization and deforestation in the Brazilian Amazon, in light of the environmental Kuznets curve (EKC) theory. The main relationships are summarized by a general typology, considering municipalities as the unit of analysis and the evolution of a set of socioeconomic variables and deforestation data as the metrics associated with urbanization and environmental degradation. The Pará state was chosen as the pilot area for this study. The last two demographic censuses, in 2000 and 2010, defined the time interval for analyzing the interactions between changes in deforestation and the overall changes in socioeconomic variables at the municipality level for the study period. The EKC approach included spatial analysis methods to also consider the spatial heterogeneity in the variables' relationships, adopting the proposal of Oliveira et al. (2011) as one of the main bases for methodological delimitation. It is noteworthy that the spatial approach is fundamental to understanding the possible interactions between socioeconomic, demographic, and environmental variables in the Amazon, a region with important intra-regional differences (Rindfuss and Stern 1998, Sathler et al. 2018).

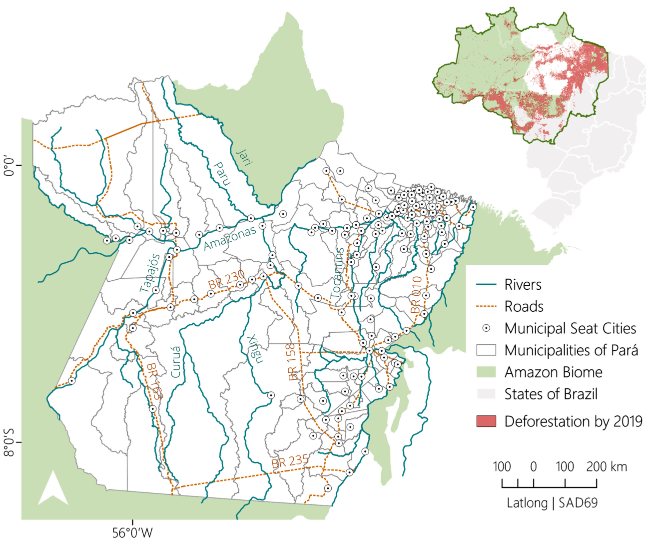
However, it is recognized that the limitations of the EKC conceptual-methodological proposal discussed in the literature must be considered to ensure the transparency of the process and the integrity of the results. To get around the main problems previously highlighted, in addition to the income variable, a set of socio-demographic and economic variables derived from the census data was taken into the model. In addition, the local spatial analysis method aims to generate spatialized and individualized results. In this context, the average of the income variable is associated only with the borderline neighborhood, minimizing errors associated with the overestimation of the income turning point. Thus, this work contributes to the discussion about the influence of different strategies for regional economic development that could support "sustainability." In the context of Amazon cities, the term sustainability is understood as the capacity for social and economic evolution dissociated from predatory uses of forest resources. The complexity between possible and probable development paths for the future of the Amazon is discussed, emphasizing the importance of thinking and acting from a regional perspective, highlighting the potential differences, in the context of this analysis, between "cities in the forest" and "cities of the forest."

METHODOLOGY

Study area

The study area comprises all 144 municipalities in the state of Pará (Fig. 1). The complexity of socioeconomic characteristics, population dynamics, and deforestation rates makes Pará an adequate object of analysis to explore the EKC relationship patterns and the different types of cities' socioeconomic evolution. Pará is one of the nine states of the Brazilian Legal Amazon. The mosaic of land uses and land cover in Pará resulted from a multiplicity of actors and processes along with its occupation history. In the course of this history, endogenous and exogenous economic initiatives acted as the underlying driving forces of the processes of change in the forest landscape.

Fig. 1. Study area: Pará State, Brazil.



Until the 19th century, the process of the formation of the Amazon urban space was associated with building strategic bases to exercise control over the territory and its people, without interest in settlement and regional development. Then, in the 20th century, to favor the expansion of the agricultural frontier, the focus was on the attraction of migratory flow and organization of the labor market, culminating in tax incentives to attract companies and infrastructure networks that favored the urbanization of the population and the territory around the main cities. Later, in the 21st century, these city-centered spaces acted as a political-economic base in the industrialization process (Corrêa 1987, Becker 2013), constituting a hybrid urban reality that, although it concentrated political power in municipal cities, it still preserved layers of other ways of life and economic integration modes hidden, but alive, in the forest (Cardoso et al. 2016).

From 2000 to 2010, the population in Pará grew at an average annual rate of 2.04% (IBGE 2000, 2010*a*), while in Brazil, the average annual rate was 1.17% (IBGE 2000, 2010*a*). This fast population growth is also reflected in the urban population. Among the states of the Legal Amazon, Pará presented the highest urban population growth rate in the last decades: 16.02% between 1991 and 2010. Aside from the intense population dynamics, Pará has had the highest deforestation rates in the Brazilian Amazon since 2006. Estimates showed that more than 148 thousand km² have been deforested since 1988, which is equivalent to 34% of the deforestation recorded for the entire Legal Amazon (INPE 2020). In general, the expansion of the agricultural frontier and the intense forest loss occurred mainly where the arc of deforestation advances over the mesoregions of the southeast and southwest of Pará (IBGE 2005, INPE 2020).

Pará is a state with a complex economy. The economic activities are concentrated in the mining and timber extraction sectors, services, and agriculture; mainly with expansion in agriculture due to soy production (FAPESPA 2016). In 2015, the GDP value of the state represented a contribution of 2.2% of the national GDP and 40.8% of the GDP of the North region (FAPESPA 2017). However, even with this expressive contribution to the regional economy, Pará had the lowest human development index (HDI) in the region (0.646 in 2010), being the seventh-worst index value in the country (UNDP 2010). These characteristics and ambiguities, added to the historical-geographic context, highlight the state of Pará as an important object of study for analyzing the relationships between current development models and their possible consequences on the dynamics of forest loss.

Materials and methods

Originally, the EKC model included the data per capita income, considering its quadratic term. However, some studies explore other shapes of the curve in addition to the traditional inverted "U" using the cubic and logarithmic forms of the data (Gomes and Braga 2008, Carvalho and Almeida 2010, Tsianikoudis et al. 2019). Because the study area is located in a forest biome, in this analysis, we have taken deforestation as a measure of environmental degradation because it represents loss, at different levels, of natural capital. The general specification applied also considers its cubic shape, so that other EKC formats can be explored, in addition to the original inverted "U" (Equation 1):

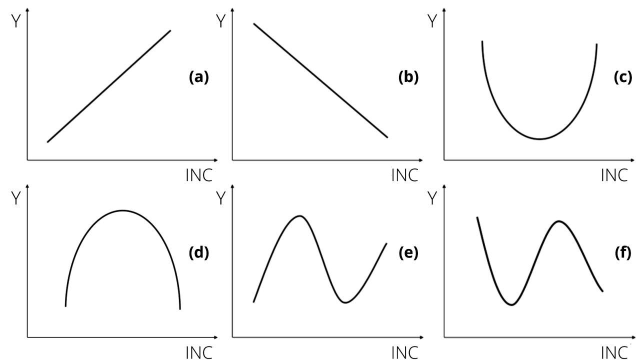
$$\text{Deforestation} = \beta_0 + \beta_1 \text{INC} + \beta_2 \text{INC}^2 + \beta_3 \text{INC}^3 + z\alpha + \varepsilon \quad (1)$$

where Deforestation is the variable of interest (Y), *INC* is the per capita income, *z* is a vector that includes the other explanatory socioeconomic and environmental variables, ε is the term of random error, and α and βi are the regression parameters. The βi coefficients determine the shape of the curve that relates deforestation to its development profile, for each municipality.

Considering the quadratic and cubic terms of income, six relationships, or shapes of the EKC curve, could be identified from the model:

1. increasing monotonic linear relationship: when β1 is higher than 0 and β2 and β3 are not significant (Fig. 2a);
2. decreasing monotonic linear relationship: when β1 is lower than 0 and β2 and β3 are not significant (Fig. 2b);
3. "U" shaped relationship: when β1 is lower than 0, β2 is higher than 0, and β3 is not significant (Fig. 2c);
4. traditional inverted "U" format: when β1 is higher or equal than 0, β2 is lower than 0, and β3 is not significant (Fig. 2d);
5. "N" format relationship: when β1 is higher or equal to 0, β2 is lower than 0, and β3 is higher than 0 (Fig. 2-e);
6. inverted "N" format: when β1 is lower than 0, β2 is higher than 0, and β3 is lower than 0 (Fig. 2f).

Fig. 2. Examples of predicted relationships between the variable of interest (deforestation) and the explanatory variables in terms of the environmental Kuznets curve (EKC).



(a) increasing monotonic relationship; (b) decreasing monotonic relationship; (c) "U" shaped relationship; (d) inverted "U" relationship; (e) "N" shaped relationship and (f) inverted "N" shaped relationship.

Based on the theoretical foundation that supports this work, it is expected that the result of the EKC presents the inverted "U" shape, as described in the original model (Grossman and Krueger 1991, 1995). Initially, the increase in deforestation would reflect economic activities related to forest conversions, such as conversion to agriculture and livestock activities. As the municipality develops its economy, its portfolio of socioeconomic indicators should evolve with its urbanization process, and a reduction in deforestation should be expected. However, deforestation decreases can happen in different situations, not all positive, like the depletion of the forest resource, command and control policies, environmentally aware economic strategies associated with local environmentally aware populations, and environmentally aware urban policies (Selden and Song 1994, Bretschger and Smulders 2000, Becker 2009).

The EKC proposal originally reinforces the rationality of natural resources overexploitation when it suggests that the market alone can induce the necessary measures for social inclusion and environmental sustainability. However, in this work, we propose expanding the analysis of regional development beyond the income-only economic aspect. We analyze the relationship between environmental degradation and development not only by the growth of per capita income but also by a set of variables that represent different axes of territorial development. These

Table 1. Description, supporting references, and data source of the initial variables used for the model applied to the environmental Kuznets curve (EKC).

Dimensions	Variables	Supporting References	Data Source
Deforestation	Accumulated deforestation (km²).	Rodriguez et al. 2009, Tritsch and Arvor 2016	Satellite Program for Monitoring the Deforestation of the Brazilian Amazon Forest (PRODES)
Income	Municipal per capita income (R$).	Tritsch and Arvor 2016, Caviglia-Harris et al. 2016	Instituto Brasileiro de Geografia e Estatística (IBGE)
Human Development	Municipal human development index.	Rodriguez et al. 2009, Caviglia-Harris et al. 2016	United Nations Development Programme (UNDP)
Inequality	Theil-L† inequality index.	Guedes et al. 2012	Instituto de Pesquisa Econômica Aplicada (IPEA)
Violence	Number of homicides in a year (units).	Moran 1993	IBGE
Education	Expectation of years of study in the population aged 18 (years).	Tritsch and Arvor 2016	-
	Population, aged 25 or over, with higher education (%).	-	-
	Population, aged 18 or over, with primary education (%).	-	-
	People in households vulnerable to poverty, and in which there are no residents with complete primary education (%).	-	-
Health	Aging rate (ratio between the population aged 65 and over and the total population multiplied by 100).	Sathler et al. 2018	Departamento de Informática do Sistema Único de Saúde (DATASUS)
	Life expectancy at birth (years).	-	-
	Infant mortality (number of children who will not survive the first year of life in every 1000 children born alive).	-	-
	Probability of survival to 60 years (years).	-	-
Basic Services	Population with piped water (%).	Tritsch and Arvor 2016	IBGE
	Population with electricity (%).	-	-
	Population with garbage collection (%).	-	-
Labor	Employees, aged 18 or over, with a formal contract (%).	Becker 2013	IBGE
	Employees, aged 18 or over, in the public sector (%).	-	-
	Employees, aged 18 or over, in the agricultural sector (%).	-	-
	Employees, aged 18 or over, in the mineral extraction sector (%).	-	-
	Employees in the industry (%).	-	-
	Employees in the service sector (%).	-	-
	Number of self-employed workers (units).	-	-

†Theil-L index is the logarithm of the ratio between the arithmetic and geometric averages of individuals' per capita household income. If the ratio between the averages is equal to 1, the index will be equal to zero, indicating a perfect income distribution. The higher the ratio between the averages, the higher the value for Theil's index, and the worse the income distribution (Theil 1967, as cited in Hoffman 1991).

axes represent characteristic elements of urban transformations through their infrastructure and/or services.

Therefore, we defined a set of additional explanatory variables (z; Equation 1), selected based on the literature (Moran 1993, Rodrigues et al. 2009, Guedes et al. 2012, Becker 2013, Galego-Alvarez et al. 2014, Caviglia-Harris et al. 2016, Tritsch and Arvor 2016, Sathler et al. 2018). Altogether, there were 22 initial independent variables in the exploratory analysis, comprising the following dimensions: education, health, income, labor, human development, inequality, violence, and basic services (Table 1). These variables were chosen from the compilation of work proposals whose main axis of discussion is the relationship between deforestation and socioeconomic development in the Amazon.

The values for these variables, associated with the municipality, come from census surveys and other public demographic data collection platforms. The dependent variable, deforestation, corresponds to the total accumulated deforestation by municipality up to 2000 and 2010, and it comes from the Satellite Program for Monitoring the Deforestation of the Brazilian Amazon Forest (PRODES; INPE 2015). The data availability for the socioeconomic variables used in the characterization at the municipality scale restricted the analysis to the 2000 and 2010 periods. The value difference for the period (2000-2010) was computed for each variable and its expected relationship with the difference in accumulated deforestation (2010-2010 in km^2) is described in Table 2.

The analysis of the EKC relied on the results of the model expressed in a local spatial regression method, the GWR (Brunsdon et al. 1996, Fotheringham et al. 2002, Charlton et al. 2009). The GWR allows the model to estimate the parameters of localized linear regressions and it is adequate for evaluating a local model of the variable or process being investigated considering its spatial nonstationarity condition. The model estimates linear regressions for each spatial unit, i.e., the municipality, in this case, using a subsample of data based on an established neighborhood rule. In this sense, the GWR provides a set of estimates that fits local characteristics, which means, they are in accordance with the municipalities and the conditions of their surroundings, captured by the model's neighborhood rule (Equation 2):

$$Y_i = \beta_0(u_i, v_i) + \Sigma\, k\, \beta k(u_i, v_i) X_{ik} + \varepsilon_i \qquad (2)$$

where (u_i, v_i) represents the coordinates of point i in space, and β_k (u_i, v_i) refers to the value that the continuous function β_k (u, v) assumes at point i.

Table 2. Explanatory variables included in the econometric model and the expected (– or +) relationship sign.

	ID	Variables	Expected sign (- or +)
Y	DAD	Difference in accumulated deforestation (km²).	
X	DINC	Difference in per capita municipal income (R$).	(-)
	$DINC^2$	Square of the difference in municipal per capita income.	(-)
	$DINC^3$	Cube of the difference in municipal per capita income.	(-)
(z)	DMHDI	Difference in the municipal human development index.	(-)
	DTHEILI†	Difference in Theil-L† inequality index (Theil 1967 apud. Hoffman 1991).	(+)
	DHOM	Difference in the number of homicides (units).	(+)
	DEYS	Difference in the expectation of years of study in the population aged 18 (years).	(-)
	DPPHE†	Difference of the population, aged 25 or over, with higher education (%).	(-)
	DPPPE†	Difference of the population, aged 18 or over, with primary education (%).	(-)
	DPHVUL†	Difference of people in households vulnerable to poverty, and in which there are no residents with complete primary education (%).	(+)
	DRTAG	Difference in the aging rate (ratio between the population aged 65 and over and the total population multiplied by 100).	(-)
	DLEB	Difference in life expectancy at birth (years).	(-)
	DINFM†	Difference in infant mortality (number of children who will not survive the first year of life in every 1000 children born alive).	(+)
	DPSUR†	Difference in the probability of survival to 60 years (years).	(-)
	DPPWAT	Difference of the population with piped water (%).	(-)
	DPPE†	Difference of the population with electricity (%).	(-)
	DPPGC	Difference of the population with garbage collection (%).	(-)
	DPEFC	Difference of employees, aged 18 or over, with a formal contract (%).	(-)
	DPEPS	Difference of employees, aged 18 or over, in the public sector (%).	(-)
	DPEAS	Difference of employees, aged 18 or over, in the agricultural sector (%).	(-)
	DPEMES	Difference of employees, aged 18 or over, in the mineral extraction sector (%).	(+)
	DPEIND	Difference of employees in industry (%).	(+)
	DPESS	Difference of employees in the service sector (%).	(-)
	DSEW	Difference in the number of self-employed workers (units).	(-)

†Variables excluded from the model after multicollinearity analysis.

A set of exploratory analysis of spatial data (AEDE) techniques was used to test for the presence of multicollinearity, the assumptions of linearity, and the presence of spatial dependence. From the collinearity analysis, the model was established considering the combination that reached a value of variance inflation factor (VIF; Berk 1977) less than 10 (Tamhane and Dunlop 2000, Kutner et al. 2004, Miles 2014) to ensure that there are no severe multicollinearity issues in the dataset.

For the general specifications of the GWR, a traditional Gaussian model was considered. The GWR method works with three types of regression models: continuous, binary, and count models, which are usually assigned in the statistical literature as the Gaussian, Logistics, and Poisson distribution, respectively. The Gaussian model is applied when the dependent variable can take on a wide range of values, as in the case of the variable here under analysis, deforestation. Furthermore, it was found that the values of the dependent variable are grouped symmetrically around the mean, characterizing a normal distribution, thus responding to yet another criterion for using a Gaussian model.

The geographical coordinates of the municipal seat city identified each municipality (Fig. 1). Because these are non-contiguous sample points, the adaptive kernel function with an automatic band selection criterion, i.e., golden section (Greig 1980), based on the cross-validation method (CV) was adopted. From the identification of the EKC curves type (Fig. 2) and the values of the local parameters, the municipalities were grouped by the similarity of shapes and intensities of the relationships between their urbanization stages; a complex process but represented here by the evolution of the set of sociodemographic and economic variables, and their deforestation dynamics.

RESULTS

The descriptive statistics of the data set (Table 3) show that there is great variability in the deforestation variable (*DAD*) in the study area. The municipalities presented on average 542 km² of deforestation difference, ranging from zero up to 9967 km², and 1111 km² of standard deviation. From the total of 22 variables, 14 presented negative minimum values, indicating a reduction in the value of the variable in the time interval analyzed for some municipalities. This result, for most variables, suggests losses of resources, infrastructure, and/or service over time. Negative mean values indicate that the variables have low values between the units of analysis in the analyzed period.

The multicollinearity analysis reduced the set of variables from 22 to 15 variables. The final set presented a VIF value equal to 5.86. The excluded variables were: *DTHEILI*, *DPPHE*, *DPPPE*, *DPHVUL*, *DINFM*, *DPSUR*, *DPPE* (see Table 2 for an expansion of abbreviations). After excluding the collinear variables, linearity and spatial dependence were also tested. The normality of the residuals rejected the null hypothesis of normality. The homoscedasticity of the residuals did not reject the null hypothesis of homoscedasticity for one test and rejected it for the other. Moran's test I, with the analysis of pseudo-significance (999 permutations), observed the presence of statistically significant spatial effects in the regression residuals, confirming the need for spatial methods (Table 4).

Table 3. Descriptive statistics of the variables used in the environmental Kuznets curve (EKC) model for the municipalities of Pará. Please see Table 2 for meaning of acronyms.

	Mean	Std. Deviation	Min.	Max.		Mean	Std. Deviation	Min.	Max.
DAD	541.60	1111.28	0	9966.9	DPPWAT	52.78	16.79	7.2	82.03
DINC	70.43	53.20	-72.54	228.34	DLEB	3.97	1.59	1.12	7.11
DMHDI	0.14	0.02	0.08	0.22	DRTAG	0.96	0.58	-0.52	2.88
DPEFC	5.04	6.93	-9.15	35.67	DINFM	-13.31	5.41	-24.19	-4.05
DPEPS	-0.95	3.51	-14.31	9.29	DPSUR	8.34	2.85	3.32	13.91
DSEW	-4.36	8.34	-32.87	18.53	DPPPE	16.41	4.24	7.28	34.02
DPEAS	-4.74	11.49	-36.08	42.95	DPPES	2.16	1.01	0.34	5.4
DPEMES	0.26	1.51	-7.38	10.99	DEYS	2.09	0.66	0.6	3.92
DPEIND	-4.55	8.22	-52.18	6.73	DPHVUL	-23.74	6.20	-40.48	-7.48
DPESS	1.88	5.50	-16.11	19.07	DHOM	15.29	46.67	-2	407
DPPGC	35.09	23.27	-18.83	89.71	DITHEILI	0.00	0.13	-0.36	0.48
DPPE	24.31	13.11	0.31	60.89	-	-	-	-	-

Because the model with original variables did not respond favorably to the assumptions of linearity, a *log* transformation was applied to the dependent variable (*DAD*). Logarithmic transformations enable adjusting the probabilities to a Gaussian curve, obtaining consistent results when dealing with primarily positive data (Pino 2014). From testing the linearized model, Santa Cruz do Arari was removed from the data set because it had a zero value in the deforestation variable (*DAD*). The model (Equation 3), adjusted after the analysis of the VIF and dependent variable transformation, is:

$$\begin{aligned} log(\mathrm{DAD}) = {} & \beta_0 + \beta_1 \mathrm{DINC} + \beta_2 \mathrm{DINC}^2 + \beta_3 \mathrm{DINC}^3 + \\ & \beta_n \mathrm{DMHDI} + \beta_n \mathrm{DPEFC} + \beta_n \mathrm{DPEPS} + \beta_n \mathrm{DSEW} + \\ & \beta_n \mathrm{DPEAS} + \beta_n \mathrm{DPEMES} + \beta_n \mathrm{DPEIND} + \beta_n \mathrm{DPESS} + \\ & \beta_n \mathrm{DPPGC} + \beta_n \mathrm{DPPWAT} + \beta_n \mathrm{DLEB} + \beta_n \mathrm{DRTAG} + \\ & \beta_n \mathrm{DEYS} + \beta_n \mathrm{DHOM} + \varepsilon \end{aligned} \tag{3}$$

After the logarithmic transformation, the assumptions of linearity and the presence of spatial effects in the model were again evaluated. The normality test of the residuals failed to reject the null hypothesis and similarly, the homoscedasticity tests of the residuals failed to reject the null hypothesis. With the model aligned with the assumptions of linearity, Moran's test I, with the analysis of pseudo-significance (999 permutations), observed the presence of statistically significant spatial effects. The global results of general adjustment of the variables in the GWR model showed that, compared to the non-spatial regression, the determination coefficient had a better adjustment using the spatial method. In addition to the determination coefficient, the Akaike value also indicated an improvement in the fit of the spatial model compared to the values found in the non-spatial regression (Table 4).

Figures 3 and 4 represent, respectively, EKC patterns and the local parameters estimated by the GWR model on municipalities' maps (Tabular data can be made available upon reader's request.). The dynamics of deforestation (Log (*DAD*)) as a function of per capita income (*DINC*, *DINC*², and *DINC*³) and other socioeconomic variables were not statistically significant (95% confidence were considered +/- 1.96 t-statistic) for the northeastern region of Pará, comprising the Metropolitan Region of Belém and its surroundings. This result is associated with the historical and geographical characteristics of the region. Because this area is contiguous with Belém, it receives the influence of an established and consolidated urban infrastructure, consequently of higher values of socioeconomic indexes. Additionally, forest resources have long been intensively exploited, as indicated by the low values of deforestation in recent dates. In 2019, Belém presented only 21.46% of forest area concerning the municipality area, whereas for the entire state of Pará, for example, this value reached 69% (INPE 2020).

When considering the spatial relationships present in the model of 15 complementary socioeconomic variables, only 4 were statistically significant. This result was expected because the theoretical-conceptual basis of this work assumes that, although interconnected, there are no direct and/or causal relationships between urbanization and deforestation in the Brazilian Amazon. These processes are subject to forces and agents that respond to different interests and act on different scales. It is also noteworthy that three of the four significant variables correspond to types of work, which shows the relevance of this aspect in the urban development process, corroborating the ideas proposed by Jacobs (1969) and discussed by Becker (2013) when highlighting the importance of restructuring of forms of work as a means to guarantee a more sustainable future for the Amazon, based on production and work systems compatible with a forest region.

For all municipalities in which the relationships were statistically significant, the variables difference in the percentage of employees with a formal contract (*DPEFC*; Appendix 4, Table A4.1), difference in the percentage of employees in the mineral extraction sector (*DPEMES*; Appendix 4, Table A4.2), and difference in the percentage of employees in the service sector (*DPESS*) were positively related to the variation in deforestation (Log (*DAD*)). On the other hand, the difference in the percentage of the population with garbage collection (*DPPGC*; Appendix 4, Table A4.4) had a negative relationship with the variation in deforestation during that period. It is noteworthy that the spatial variation of the local coefficients for these complementary variables (*DPEFC*, *DPEMES*, *DPESS*, and *DPPGC*), as a function of the deforestation dynamics (Log (*DAD*)), should not be interpreted as a direct contribution of these variables to the

Table 4. Main results of the adjustment analysis and linearity assumptions of the analyzed models (ordinary least squares and geographically weighted regression, or OLS and GWR).

Models	Adjustment		Normality	Homoscedasticity		Spatial Dependence
	Determination Coefficient (R^2)	Akaike (AICc)	Jarque-Bera	Breusch-Pagan	Koenker-Basset	Moran's I
Original (OLS)	0.34	2367.35	414.37 (p-value 0.00)	87.58 (p-value 0.00)	18.99 (p-value 0.26)†	0,28
Logarithmic (OLS)	0.23	262.62	0.28 (p-value 0.86)†	19.09 (p-value 0.26)†	21.01 (p-value 0.17)†	0.30
Logarithmic (GWR)	0.49	208.31	-	-	-	-

†Significance to 5%

forest conversion process. Instead, they are a synthesis of the socioeconomic profile, variating according to the pattern of deforestation evolution.

DISCUSSION

The different shapes of EKC, observed in the context of the proposed analysis, respond to different occupation processes and socioeconomic contexts that represent different types of urbanization and their dynamics of deforestation. The "U" shaped priority pattern may be related to a type of urbanization and socioeconomic development that historically establishes a predatory relationship with natural resources. This result reflects the historical development of industrialization in the Amazon territory, described by Becker (1982) as an unequal process based on the valorization of raw materials and submission to the economic interests of the international market. Defined as a "resource frontier," i.e., a settlement and productivity area in a virgin territory (Becker 1982), the presence of large-scale and economically profitable natural resources made the Amazon a place for development orbiting the economy of large centers, submitted to political force as a potential for national integration (Santos 2013).

The irregular distribution of the Amazonian population promotes physical and cultural isolation that suppresses the sense of community, facilitating the penetration of modern society in these spaces (Becker 1982, 2013, Pandolfo 1994). The construction of federal roads, between the 1960s and 1980s, linked the Amazon to the country's major economic centers, facilitating the trade of raw materials that reinforced the colonialist and unbalanced economy (Becker 1982, Santos 2013). As well, the emergence of the capitalist industry changed the power of urban mediation in the Amazon territory (Silva 2021) understood since the colonial period as a space of power, celebration, and exchange and which with the advent of the urban-industrial model became interpreted as a space for production and consumption.

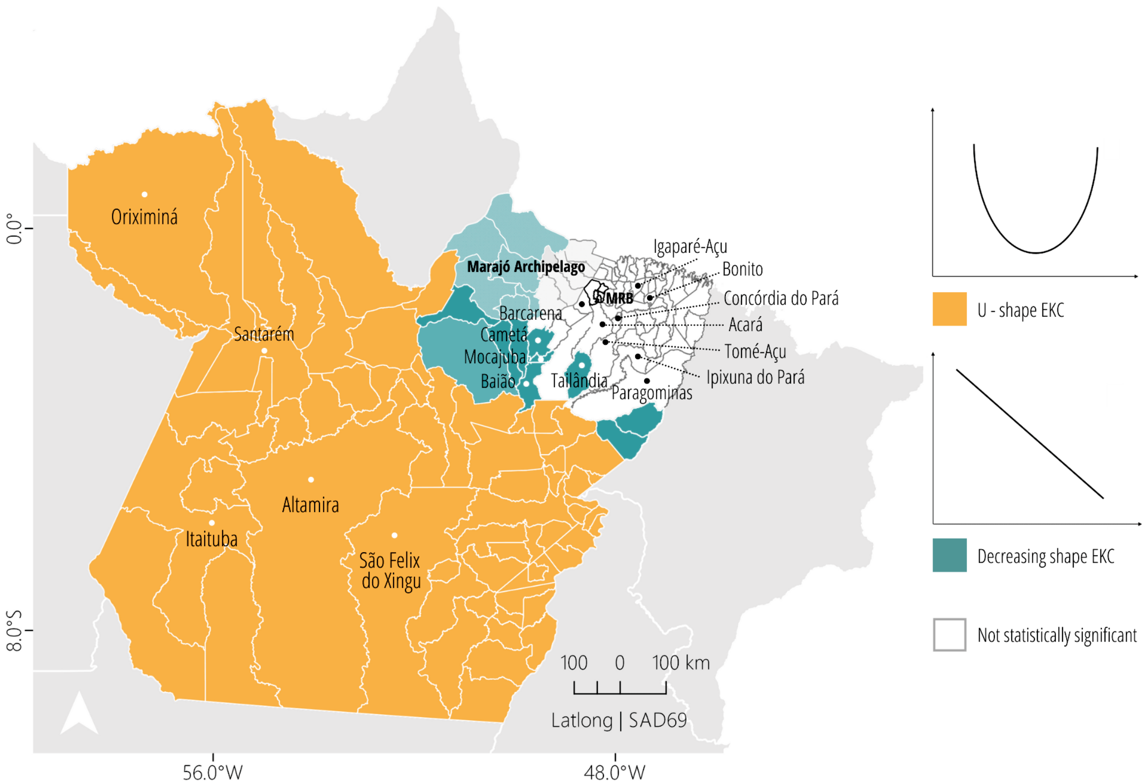
The reduction in deforestation at the beginning of the "U"-shaped EKC curve describes a profile of the evolution of socioeconomic development that reflects the trend to contain deforestation in this region up to a given moment, represented by the inflection of the curve. However, the change in the trajectory of the curve demonstrates that the command-and-control policies are not capable, by themselves, of refraining forest conversion practices in the long term. This dynamic shows the strength of industrialization in the process of transforming the territory, and its relationships that seeking to homogenize and align production, consumption, and lifestyle patterns with commercial logic, ignores the potential of diversity and reinforces the domain of exogenous agents and export logic (Monte-Mór 1994, Santos 2009, 2013).

On the other hand, the EKC's decreasing monotonic shape illustrates a type of socioeconomic development that converges with the reduction of deforestation. As the municipality reaches higher socioeconomic conditions, deforestation reduces. All municipalities with decreasing monotonic EKC curves (Fig. 3) registered an increase in their rural population, suggesting that EKC considers the importance of the rural economy for the region. In the Marajó Archipelago, the municipalities presented less than 10% of deforestation over the total area of the municipality (INPE 2020). The increased value of the floodplain products in the market, together with the policies of legalization of land tenure, helped to maintain the viability of the rural economy (Costa and Brondízio 2011). In the region, the increase of livestock occupied mainly native pasture areas of poorly drained savannas (Arima and Uhl 1996), conserving the natural forest landscape. In addition to the livestock, the island's economy is based on fishing and extraction of açaí and rubber.

Other municipalities in the group, such as those in the Mocajuba region, are part of an important açaí producing region, comprising the mesoregions of Northeast of the state of Pará, some municipalities of the Marajó archipelago, and of the Metropolitan Region of Belém (MRB; Costa et al. 2018), which have the fruit extraction as the main base of the local economy. The açaí economy is known to be important for sustainable and inclusive development. It is based on peasant forms of management and the industrial process is associated with small and medium-sized companies based on local socioeconomic potential (Costa et al. 2018). The production and consumption of açaí in this region illustrate how the deepening of relations between the urban base and the agro-extractive economies can create alternative urban development models (Silva 2021). The idea of "producing to conserve" (Becker 2013) overcomes the industrial logic, seeking development strategies based on economic dynamism and maintenance of natural and social diversity.

In contrast, the capitalist-industrial expansion, by transforming resources and means of production, changes the relationship between society and nature. Underlying industrialization and corporate urbanization (Santos 2013) direct its interests toward economic relations and neglects the existence of people who inhabit and make a living from the territory, manifesting what Castro (2009) calls "cities in the forest." Development models, which are environmentally responsible and socially fair, require

Fig. 3. Map of observed environmental Kuznets curve (EKC) standards for municipalities in the State of Pará.



an understanding of the possibilities of economic growth, mediated by urbanization and by the inherent dynamics of nature itself (Siva 2017). It may be possible to promote cities as strategic places for the endogenous organization of the regional productive structure, resuming the society-nature relationship as represented by the "cities of the forest" (Browder and Godfrey 2006).

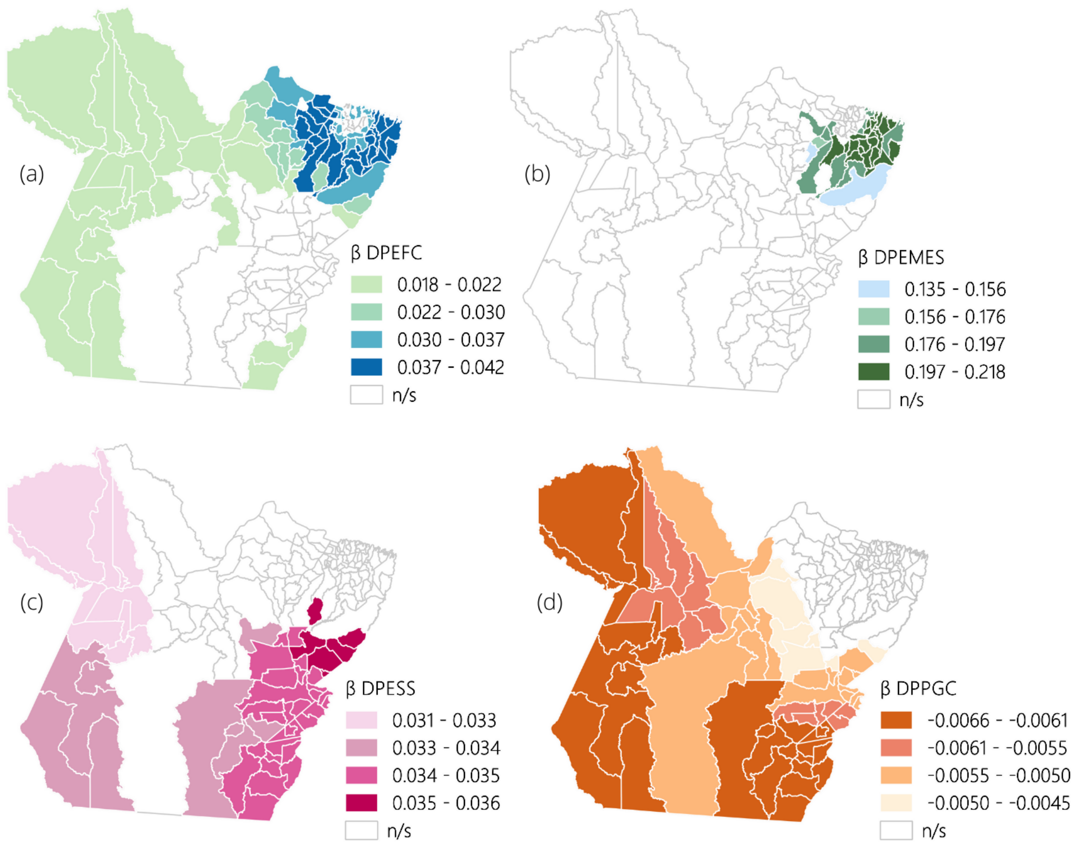
Additionally, the results of the complementary variables express the spatial variability of the municipal socioeconomic profiles, or the precariousness of the urban territories, according to the pattern of deforestation evolution. As previously described, the variable *DPEFC* (difference in the percentage of employees with a formal contract between 2000 and 2010) is positively related to the variation in deforestation (Fig. 4a). This relationship suggests that the evolution of deforestation could be associated with the creation of new formal jobs, which could lead to the heating of the local economy. Higher *DPEFC* values are concentrated in the northeast of the state, close to the Metropolitan Region of Belém, which was expected because public agencies, service companies, and commerce are concentrated in this region of the state. A non-significant area in the southeastern portion of the state is where the deforestation frontier advances. This spatial distribution follows the economic dynamics of Pará. Industrialized regions and centralities, such as the Metropolitan region, generate more formal jobs and offer services. Consequently, in these regions, economic activities associated with formal jobs contribute more to explain the growth of deforestation.

Furthermore, there are municipalities whose productive structures are mainly supported by exploiting the potential of Amazonian biodiversity, and the production and transformation processes create demands in the labor market. For example, the production of manioc, açaí, and coconut in the lower Tocantins region; of palm oil in the northeast of Pará, mainly in the municipalities of Acará, Bonito, Tailândia, Tomé-Açu, and Concórdia do Pará; and of black pepper, concentrated in Tomé-Açu, Igarapé-Açu, Baião, and Cametá, showcase some of the examples of the potential biodiversity in the productive systems that have at their center ways of producing associated with adequate management of the culture in coexistence with the surrounding forest landscape.

The *DPEMES* variable (difference in the percentage of employed persons in the mineral extraction sector) is also positively related to deforestation in a small group of municipalities in the northeast of Pará (Fig. 4b). Among the statistically significant municipalities for this relationship, Barcarena, Paragominas, Ipixuna do Pará, and Cachoeira do Piriá are some of the main mining municipalities in the state. Because mineral extraction and transformation are their main economic base activities, these municipalities stand out in the results for this variable. The positive relationship between mining and deforestation is highlighted by Sonter et al. (2017) when explaining that due to combined factors, i.e., land use displacement, development of commodity supply chains, urban expansion, and waste disposal, the effects of deforestation can reach large extensions and areas far beyond their operational limits.

The *DPESS* variable (difference in the percentage of employed persons in the service sector) presented a positive relationship

Fig. 4. Maps of the local coefficients for the significant complementary variables.



(a) DPEFC - difference in the percentage of employees with a formal contract; (b) DPEMES - difference in the percentage of employed persons in the mineral extraction sector; (c) DPESS - difference in the percentage of employed persons in the service sector; (d) DPPGC - difference in the percentage of the population with garbage collection.

with deforestation, observed in two groups of municipalities in the southeast and southwest of Pará (Fig. 4c). These are municipalities whose economic base is associated with both mineral exploration (the regions of Carajás and the lower Amazon (with emphasis on the exploration of bauxite in Oriximiná, and gold in Itaituba) and with livestock. Therefore, the operational aspects of their activities and their production chains, which provide infrastructure and services for the development of the activity and labor, are two associated factors that influence the dynamics of deforestation in these municipalities.

Finally, the variable *DPGC* (difference in the percentage of the population with garbage collection) is negatively related to deforestation and presents higher values in two deforestation frontiers, southeast and southwest of Pará (Fig. 4d). Municipalities with household waste collection services indicate urban structures that are more consolidated, opposing the dynamics of deforestation, associated with agricultural regions, and less structured urban development.

Considering the spatial variability of the evolution of the processes under analysis, the results confirm Sathler et al.'s (2018) hypothesis on the need for spatial methods to investigate socioeconomic and environmental processes from spatialized responses. Relationships between deforestation and socioeconomic development in the Amazon were previously discussed by Santiago and do Couto (2010) and Tritsch and Arvor (2016), however, these authors used non-spatial analysis approaches. Santiago and do Couto (2010) studied the entire Brazilian territory, and therefore, data were considered to provide generalized answers for the country, without considering regional particularities. On the other hand, studying the Brazilian Legal Amazon, Tritsch and Arvor (2016) considered only three socioeconomic variables to represent the general relationship between socioeconomic development and different classes of deforestation frontiers. Although in this study, the authors tried to observe a relationship between deforestation and a small set of socioeconomic variables, however, the objective is to attempt to characterize factors associated with deforestation frontiers and not with the urbanization process.

Therefore, our results complement previous analyses by Tritsch and Arvor (2016) by considering a more robust dataset, with a greater capacity to represent the socioeconomic reality and evolution of deforestation in the Amazon region. Our results also contribute to the discussions raised by Santiago and do Couto (2010) by providing a more specific, and consequently, more in-depth view, which contextualizes the interpretation of socio-demographic and economic variable analysis as a dimension of urbanization. That said, the greatest contribution of this work lies in the proposition of a methodological approach that considering the spatial heterogeneity of the Amazon territory and the spatial dependence of the variables, provides individualized EKC curves for each municipality through local spatial analysis. Furthermore, the set of explanatory variables in this work aims to represent the social, demographic, and economic transformations related to the population and the territory urbanization at the municipal scale.

CONCLUSIONS

Our work proposed to analyze the impact of different urbanization developments based on the analysis of some variables linked to socio-demographic and economic development features, with the dynamics of the deforestation in the Pará Amazon region, establishing municipalities as the unit of analysis. In the light of the environmental Kuznets curve (EKC) theory, we identified two base-type curves, i.e., decreasing monotonic and "U" shapes, which describe the relationship between the subset of socio-demographic and economic variables, representing the evolution of urbanization and the dynamics of deforestation for the municipalities of the state of Pará.

The use of GWR to map the spatial variability intrinsic to the modeled phenomena enabled the observation of different forms of relationships between the variables. In general, in the context of the Pará Amazon and consolidated economy scenarios, deforestation and income tend to converge. The prevalence of the "U"-shaped EKC illustrates the contradiction generated by the incorporation of the Amazon into urban-industrial economic dynamics. The industrial economic model, based on the logic of production and accumulation, acts as a mediator for the transformation of natural resources, space, and consequently, the relationship between people and their territory. Although the Amazon is considered a frontier region of natural resources, the forest assets will be exploited in an accelerated and predatory way unless other development paths are considered. A development agenda without a sustainability strategy is unsustainable in the long term. Searching for alternative models is essential for the conservation and maintenance of the Amazon economic, cultural wealth, and diversity, i.e., its socio-biodiversity. Planning and building a future, not only for the forest but also for the people who live there, is essential.

The results of the EKC curves show that pre-industrial production systems remain alive in contemporary Amazonia and represent alternatives for the recovery of the links between development and sustainable use of forest resources (Costa 2019). The decreasing monotonic EKC curve shows a disconnect between the evolution of socio-demographic and economic variables and deforestation over a period of time. The municipalities in this group are characterized by productive systems that operate in greater harmony with a forested landscape, that is, based on regional socio-biodiversity resources, according to the concept of the "cities of the forest." On the other hand, the "U"-shaped EKC curve shows an initial trend toward a reduction in deforestation which, according to socio-demographic and economic variable evolution, undergoes an inversion point and starts to have a concurrent trajectory in the other direction. This curve was predominant in the state of Pará, representing the strong influence of capitalist industrialization on the current urban patterns of development in the Amazon, as characterized by the concept of "cities in the forest." This development project is based on the association between exogenous and endogenous capital, which, from the actions of a local elite, imposes an urban-industrial pattern of territory transformation that disregards the dynamics of nature and the interests of the population.

Regionally based planning, designed to contribute to the autonomy of cities, develop the economy, and add value to the diversity of regional resources, can promote socio-demographic advances with a concomitant reduction in deforestation activity. In this context, it is possible to highlight the importance of the geopolitical strategies described by the concept of "cities of the forest" as an alternative to detach themselves from industrial standards and to prioritize new economies and social and environmental relations. The resumption of traditional production bases, associating local technologies and knowledge with new ones, aiming at valuing regional potential, would result in a spatial awareness more capable of promoting the use and management of the forest's natural resources without destroying them, updating the traditional knowledge, i.e., about the ways of producing and living in Amazonia, and promoting economic autonomy. Thus, we can think of building a pattern of urban development that is socially and environmentally compatible with a forest biome.

Responses to this article can be read online at:
https://www.ecologyandsociety.org/issues/responses.php/13224

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Data Availability:

The code that supports the findings of this study is available in Appendix 2 of the manuscript. The data were schematized and made available in Appendix 1 and were derived from the following resources available in the public domain: INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Demographic census 2000. [online] URL: http://www.ibge.gov.br/home/estatistica/populacao/censo2000/. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Demographic *census 2000. [online] URL: http://censo2010.ibge.gov.br/. INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS (INPE). Data by municipality 2000 and 2010. [online] URL: http://www.dpi.inpe.br/prodesdigital/prodesmunicipal.php. UNITED NATIONS DEVELOPMENT PROGRAM (UNDP). Atlas for human development. [online] URL: http://www.atlasbrasil.org.br/.*

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Appendix 1

Table A1.1 – Input dataset to GWR model and EKC curves analysis.

MUNICIPALITIES	Log(DAD)	DINC	DINC²	DINC³	DMHDI	DITHEILI	DHOM	DEYS	DPPHE	DPPPE	DPHVUL	DRTAG	DLEB	DINFM	DPSUR	DPPWAT	DPPE	DPPGC	DPEFC	DPEPS	DPEAS	DPEMES	DPEIND	DPESS	DSEW
Abaetetuba	2,75	86,17	7425,26	639835,40	0,13	-0,10	37	1,82	3,21	16,45	-16,29	0,98	2,91	-13,87	6,42	29,99	22,01	19,91	7,54	-0,81	4,31	0,33	-5,61	0,51	0,06
Abel Figueiredo	1,60	72,56	5264,95	382025	0,11	0,13	8	1,67	3	12,39	-25,11	1,50	5,48	-8,90	6,22	61,33	11,59	28,71	1,10	1,80	-0,29	0,26	-10,21	1,83	6,08
Acara	2,63	39,27	1542,13	60559,56	0,16	0,02	8	2,15	1,58	12,82	-14,84	0,82	2,60	-17,40	10,68	51,13	47,53	24,52	5,42	0,34	7,04	0	-23,86	7,49	-6,22
Afuá	0,92	16,73	279,89	4682,60	0,16	0,27	8	2,18	1,96	13,03	-25,42	0,48	3,80	-9,07	6,04	7,2	25,66	1,25	-1,60	0,95	-3,64	-0,15	-7,56	7,75	-17,06
Água Azul do Norte	2,80	-3,20	10,24	-32,76	0,19	-0,14	-2	2,75	0,40	14,39	-20,22	0,75	7,11	-12,57	8,05	82,03	60,89	15,31	20,14	-8,01	-12,98	0	3,76	2,40	-32,87
Alenquer	2,32	50,22	2522,04	126657,30	0,13	0,09	3	2,21	2,53	10,66	-20,03	0,93	4,29	-23,06	13,75	62,07	16,92	55,38	0,72	-1,59	-3,83	-0,14	-2,59	3,42	-3,92
Almeirim	2,54	-2,43	5,9049	-14,34	0,12	-0,21	0	2,24	5,40	10,88	-17,68	1	4,55	-14,05	8,87	23,82	8,41	11,38	-5,64	-1,33	1,73	-1,48	-6,22	2,51	7
Altamira	3,67	90,12	8121,61	731919,90	0,13	-0,04	42	1,32	3,77	13,84	-14,13	0,94	3,55	-13,50	8,93	34,35	5,17	4,56	7,04	0,31	-5,23	0,30	-2,99	3,83	-6,90
Anajás	2,20	4,81	23,13	111,28	0,18	0,13	0	3,92	1,40	12,33	-15,18	0,27	3,80	-10,29	7,16	15,07	30,01	1,25	1,52	5,08	-15,33	-0,38	1,67	7,52	-14,58
Ananindeua	1,16	184,96	34210,20	6327519	0,11	0	407	1,08	3,65	14,73	-20,28	1,26	2,05	-12,57	8,05	23,33	0,35	12,33	8,56	-2,27	0,47	0,08	-2,13	-3,57	-2,32
Anapu	3,06	39,48	1558,67	61536,31	0,16	0,04	4	3,49	2,25	17,46	-12,03	0,96	4,55	-4,53	4,71	75,74	33,89	62,02	4,47	0,55	-13,67	-0,18	-1,32	7,81	-9,54
Augusto Correa	1,36	24,18	584,67	14137,38	0,19	0,10	0	2,36	1,08	14,38	-24,27	0,21	3,96	-14,51	9,22	61,15	40,37	10,57	0,38	3,49	-11	0,07	-0,38	5,59	-1,14
Aurora do Para	2,56	14,72	216,67	3189,50	0,16	0	2	2,87	2,31	18,09	-26,39	0,64	3,94	-13,24	8,35	68,06	36,85	49,40	3,79	-0,17	-5,59	0,55	-3,18	7,68	-14,35
Aveiro	2,49	44,90	2016,01	90518,85	0,17	0,09	2	2,98	1,85	22,82	-30,21	1,74	2,35	-13,10	8,30	53,61	36,36	48,59	1,22	2	-5,06	-0,75	-0,48	5,89	-12,92
Bagre	2,23	47,27	2234,45	105622,60	0,14	0,09	1	2,51	1,21	10,89	-35,08	-0,51	6,46	-8,45	5,63	28,92	21,78	35,53	-0,05	-9,06	-14,95	0	4,12	3,04	5,03
Baião	2,39	64,95	4218,50	273991,70	0,12	-0,13	0	1,44	2,63	14,54	-23,41	0,35	3,84	-22,06	12,84	62,88	32,04	41,19	3,57	1,82	10,96	-0,2	-9,50	3,17	-0,28
Bannach	2,76	170,15	28951,02	4926016	0,17	0,28	0	1,75	0,97	18,11	-19,26	2,76	2,56	-12,84	8,14	63,73	47,06	85,52	13,25	0,43	-6,24	0,48	-1,61	5,32	3,14
Barcarena	1,99	89,40	7992,36	714517	0,11	-0,09	37	1,70	2,64	19,04	-27,70	0,29	2,76	-8,24	5,74	37,33	16,14	11,48	8,97	-1,17	-4,81	-2,96	0,99	-3,36	-3,24
Belém	1,50	228,34	52139,16	11905455	0,10	-0,06	312	0,76	5,12	13,07	-20,65	1,61	3,83	-8,40	5,91	15,60	0,31	1,22	6,29	-0,64	0,03	0,12	-3,76	-3,91	-1,40
Belterra	2,12	119,73	14335,27	1716362	0,19	0,09	0	1,92	2,84	17,37	-9,39	1,95	6,15	-10,39	7,64	52,17	43,41	33,62	-3,70	4,98	-11,39	0,25	-2,26	6,25	-7,01
Benevides	1,45	106,20	11278,44	1197770	0,14	-0,12	17	1,30	2,94	18,91	-27,54	0,70	6,44	-20,98	12,29	41,79	0,94	6,92	7,31	-6,23	-0,98	-0,25	-3,29	-6,44	3,02
Bom Jesus do Tocantins	2,33	126,43	15984,54	2020926	0,16	-0,05	17	1,69	3,44	14,81	-21,81	0,44	6,48	-20,55	12,50	68,78	22,12	25,35	11,48	-8,44	-1,70	0,22	-1,79	1,24	-3,51
Bonito	2,17	57,96	3359,36	194708,60	0,17	0,03	0	3,53	0,89	19,85	-23,60	-0,52	6,35	-22,06	12,87	63,88	43,09	77,82	16,46	-2,80	-0,41	0	6,73	-2,65	-12,61
Braganca	1,69	105,97	11229,64	1190005	0,14	0,04	3	3,07	2,75	13,90	-28,48	0,38	5,55	-22,09	12,73	33,17	20,78	28,68	6,78	0,74	-8,93	-0,05	-0,88	3,13	-1,95
Brasil Novo	3,19	118,57	14058,84	1666957	0,18	0,26	7	2,75	2,01	14,92	-19,73	2,27	6,12	-19,84	11,40	53,72	46,01	18,99	2,12	1,13	-13,08	0	-2,58	8,86	-18,19
Brejo Grande do Araguaia	2,12	87,87	7721,13	678456,30	0,10	0,02	2	0,64	2,47	16,45	-13,72	1,70	1,60	-18,65	11,73	73,30	18,03	22,24	5,90	-1,79	-16	0	0,21	-3,08	-7,46
Breu Branco	2,80	-7,49	56,10	-420,19	0,15	-0,09	23	2,53	2,06	15,62	-24,99	1,22	5,81	-6,03	4,30	69	27,57	24,84	5,33	-1,50	0,07	0,19	1,95	1,45	-0,82
Breves	2,68	39	1521	59319	0,13	0,05	14	2,09	2,51	10,46	-21,99	0,41	4,31	-19,30	11,6	25,36	10,86	35,66	-7,84	-1,09	3,94	0,05	-11,91	4,73	2,98
Bujaru	2,04	33,43	1117,56	37360,19	0,16	0,02	4	1,80	1,07	20,32	-15,90	0,77	4,06	-14,14	8,92	56,06	38,93	39,88	1,03	-1,28	7,99	0	-5,11	-3,40	5,33
Cachoeira do Arari	1,85	-24,94	622	-15512,80	0,12	-0,36	1	2,13	0,34	13,60	-28,24	0,68	3,95	-13,21	8,44	54,19	31,05	86,08	0,30	-2,27	2,43	0	-2,21	-3,95	-29,76
Cachoeira do Piriá	2,66	30,04	902,40	27108,14	0,17	0,04	0	3,39	0,66	13,47	-29,68	0,36	7,05	-12,91	8,27	65,92	29,45	20,14	-2,04	-4,93	-10,18	2,35	1,49	3,86	-13,68
Cametá	2,34	88,14	7768,66	684729,70	0,15	0,02	12	2,41	2,03	18,84	-22,73	0,38	2,92	-24,14	13,91	27,02	34,25	58,27	1,26	1,18	1,01	0,01	-3,06	0,41	2,10
Canaã dos Carajás	1,92	181,89	33083,97	6017644	0,22	-0,12	6	2,80	4,13	34,02	-27,98	0,48	5,54	-10,32	6,62	66,69	33,51	34,98	29,27	-2,85	-36,08	6,54	0,33	10,79	-22,71
Capanema	1,71	75,02	5628	422212,60	0,12	-0,08	8	1,90	1,68	13,69	-31,40	0,96	2,38	-15,87	11,03	48,38	11,05	62,39	5,09	-2,50	-2,19	0,25	-0,69	-0,93	-5,81
Capitão Poço	2,54	100,90	10180,81	1027244	0,17	-0,02	29	3,18	1,87	14,90	-18,29	1,27	5,52	-7,52	5,34	59,98	30,55	16,94	1,06	0,62	-7,12	0,07	-2,51	4,10	0,47
Castanhal	2,23	146,18	21368,59	3123661	0,12	-0,02	71	2,06	3,26	14,26	-29,32	0,94	2,73	-20,19	11,41	34,93	4,26	17,83	8,81	0,85	-2,69	0,01	-2,48	-4,13	-2,46
Chaves	1,08	73,67	5427,26	399826,90	0,16	0,33	0	2,66	1,30	7,28	-16,39	0,61	3,52	-9,83	5,63	23,74	40,11	48,92	-6,85	-4,02	6,16	0,16	-6,94	4,35	-18,81
Colares	1,41	39,28	1542,91	60605,83	0,08	-0,10	2	1,75	1,63	10,96	-26,84	1,99	2,95	-11,87	7,60	56,05	16,09	49,24	-1,92	-1,41	2,58	-0,13	-8,5	0,86	12,87
Conceição do Araguaia	2,67	101,08	10217,17	1032751	0,13	-0,13	15	1,77	3,71	18,32	-19,40	1,77	1,70	-10,13	6,61	41	12,27	14,02	6,52	-0,26	-6,91	-0,04	-0,57	-2,07	-0,63
Concórdia do Para	1,56	24,98	624	15587,53	0,16	-0,01	0	2,11	2,17	21,96	-27,56	0,41	2,01	-5,94	4,34	69,54	30,57	55,59	6,82	1,49	-11,35	-0,14	2,48	5,87	2,91
Cumaru do Norte	3,46	64,32	4137,06	266095,90	0,15	0,25	3	2,02	1,69	10,69	-38,10	0,80	4,14	-7,40	5,04	51,06	18,55	52,03	15,75	-4,04	-1,37	10,99	1,24	-8,50	5,33
Curionópolis	1,81	98,50	9702,25	955671,60	0,19	-0,01	5	2,67	2,46	24,84	-23,70	2,88	5,29	-12,88	8,42	51,05	6,85	50,65	13,21	-4,86	-13,17	1,19	-4,19	8,18	-6,33
Curralinho	2,28	11,40	129,96	1481,54	0,18	0,16	1	3,45	2,60	14,91	-34,58	0,16	6,87	-15,94	10,24	12,53	26,12	11,84	-0,48	3,97	-8,12	0	-1,12	5,30	-11,20
Curuá	1,58	58,23	3390,73	197442,40	0,20	0,17	0	2,25	5,10	27,95	-26,77	0,10	3,83	-24,19	13,7	75,54	47,05	31,85	-2,09	3,67	-17,92	-0,27	0,83	9,06	-23,06
Curuçá	1,77	15,50	240,25	3723,87	0,11	-0,35	2	1,12	0,88	14,13	-40,48	0,74	3,68	-12,53	8,04	61,74	12,01	35,73	-0,26	-0,95	1,08	0	-2,65	-2,57	-5,14
Dom Eliseu	2,95	60,04	3604,80	216432,30	0,16	-0,24	13	1,82	3,69	22,75	-21,56	0,92	6,08	-12,82	7,96	65,29	9,59	43,29	8,92	1,81	-4,2	0,14	-15,65	9,43	-5,32
Eldorado dos Carajás	2,68	76	5776	438976	0,17	-0,06	13	2,73	1,92	14,52	-33,64	1,74	2,68	-21,44	12,3	81,41	36,66	29,54	7,80	0,18	-15,3	0,27	3,62	4,22	-4,46
Faro	1,66	50,33	2533,10	127491,40	0,13	0,09	0	1,94	2,92	16,40	-26,23	1,31	5,67	-9,39	6,17	61,01	17,65	49,85	7,18	6,49	-14,72	-0,22	-3,91	10,44	-13,24

Floresta do Araguaia	2,45	101,81	10365,28	1055289	0,17	0,20	1	1,67	3,62	18,17	-16,95	1,27	3,27	-20,34	11,64	55,47	34,42	5,60	6,24	9,29	-11,77	1,65	-4,05	5,81	-3,39
Garrafão do Norte	2,23	89,35	7983,42	713318,80	0,20	-0,06	7	2,92	2,42	17,14	-29,58	1,70	5,88	-10,22	6,91	73,72	31,75	12,57	1,36	-5,14	32,06	-0,16	-41,17	2,30	-10,29
Goianésia do Para	2,88	17,84	318,26	5677,85	0,14	-0,14	28	2,16	1,79	14,91	-27,99	1,10	2,79	-20,69	11,94	61,78	22,76	74,36	8,86	-2,27	-16,97	0,12	-11,65	5,22	-1,40
Gurupá	2,01	43,13	1860,19	80230,29	0,16	0	0	1,51	0,87	14,25	-18,25	0,68	3,62	-10,07	6,44	21,09	29,62	45,47	0,91	-8,34	-1,06	-0,13	5,26	1	-4,61
Igarapé Açu	2	116,60	13595,56	1585242	0,14	0,11	-2	1,81	1,98	15,25	-25,03	1,22	2,71	-11,93	7,70	49,23	17,09	66,85	2,77	-6,72	-5,06	0	0,35	-4,93	5,25
Igarapé Mirim	2,49	31,89	1016,97	32431,24	0,13	0,01	20	2,26	1,94	12,87	-26,29	0,78	3,33	-9,78	6,30	20,90	24,99	22,44	0,07	1,36	14,37	-0,20	-13,87	0,26	2,64
Inhangapi	1,63	21,68	470,02	10190,09	0,13	-0,14	1	1,97	1,78	17,95	-23,55	0,64	2,14	-11,13	7,23	51,16	41,50	24,18	5,54	-2,74	10,04	-0,12	-21	-0,47	-1,09
Ipixuna do Para	2,91	43,73	1912,31	83625,44	0,17	-0,03	15	1,88	1,48	14,07	-29,67	0,48	3,05	-7,79	5,25	61,91	32,62	31,76	5,36	4,22	-13,81	0,89	-2,19	7,01	-8,50
Irituia	2,43	-2,81	7,89	-22,18	0,14	-0,07	11	3,03	1,80	15,42	-24,42	1,22	4,39	-10,56	6,83	49,50	38,21	32,41	3,19	-2,06	35,16	0,19	-45,21	0,17	-9,45
Itaituba	3,20	124,94	15610	1950314	0,15	-0,09	36	1,83	2,79	16,82	-24,57	1,36	6,51	-15,12	9,22	50,29	13,03	24,56	11,24	-2,28	-9,33	-0,93	0,67	-2,73	-0,49
Itupiranga	3,13	65,89	4341,49	286060,90	0,17	0,03	25	2,34	1,78	17,64	-23,79	1,30	4,58	-22,16	12,36	73,77	41,80	10,21	4,61	0,82	-17,59	-0,03	-2,09	6,53	-8,50
Jacareacanga	2,89	54,80	3003,04	164566,60	0,13	0,48	1	2,25	1,03	10,14	-30,19	0,84	3,44	-16,61	9,71	54,13	25,25	12,10	2,18	-0,61	-27,24	2,53	-1,29	19,07	-10,73
Jacundá	2,10	44,79	2006,14	89855,19	0,15	-0,08	22	2,15	2,28	18,83	-14,34	0,92	2,29	-10,82	7,06	52,36	12,79	26,60	8,85	0,57	-7,61	0,05	-10,62	1,76	-8,82
Juruti	2,09	132,73	17617,25	2338338	0,20	0,03	0	3,75	2,75	25,74	-27,95	-0,37	6,07	-8,13	5,49	59,33	31,42	61,96	14,53	-3,23	-17,89	0,88	-10,14	8,62	-8,06
Limoeiro do Ajuru	1,79	45,81	2098,55	96134,85	0,17	0,15	0	2,60	3,38	21,27	-38,17	0,20	2,92	-21,89	12,36	14,44	44,17	13,30	-1,20	-4,42	31,46	0	-10,15	-11,26	-1,15
Mãe do Rio	1,85	127,36	16220,57	2065852	0,13	0,04	9	1,46	3,56	13,39	-31,83	1,04	2,06	-10,32	6,62	65,36	18,22	51,70	6,62	-2,25	-10,89	0,06	2,52	-0,05	-2,74
Magalhães Barata	1,34	93,99	8834,12	830318,90	0,17	0,02	0	1,29	0,99	19,14	-21,49	0,50	5,54	-7,19	5,03	47,82	14,60	72,65	1,86	4,10	-20	-0,07	-0,16	6,69	18,53
Marabá	3,39	147,05	21623,70	3179765	0,13	-0,06	188	0,92	3	15,16	-31,06	0,59	4,66	-15,87	11,03	43,01	9,10	21,11	14,58	-2,10	-6,52	0,21	-1,76	-1,35	-0,82
Maracanã	1,81	92,86	8622,98	800729,90	0,16	0,12	2	2,13	1,89	16,58	-18,84	1,48	4,05	-14,61	9,53	53,57	36,18	38,19	-0,31	-1,90	-9,65	0	-2,49	2,46	4,90
Marapanim	1,80	120,65	14556,42	1756232	0,16	0,13	0	2,15	1,57	20,53	-25,59	1,51	1,12	-13,82	8,59	52,91	11,03	65,49	2,24	-4,12	1,06	0,17	-12,97	5,53	-1,90
Marituba	1,06	127,16	16169,67	2056135	0,17	-0,10	73	1,78	2,17	24,87	-25,99	0,51	6,88	-4,28	3,40	50,14	0,83	34,17	12,91	0,07	-0,85	0,01	-8,50	-5,80	-2,74
Medicilândia	3,04	-51	2601	-132651	0,11	-0,07	4	2,34	0,56	9,36	-23,15	1,19	2,77	-22,46	13,38	57,65	40,57	52,13	1,37	-4,55	6,33	-0,28	-4,99	-3,89	-3,85
Melgaço	2,18	34,99	1224,30	42838,26	0,16	0,21	0	2,69	1,78	7,31	-8,87	-0,4	6,70	-8,49	5,95	10,81	35,42	31,63	-0,45	0,92	2,23	0	-19,9	11,16	-8,73
Mocajuba	1,32	62,65	3925,02	245902,70	0,13	0,10	0	1,62	1,91	12,77	-7,48	0,87	2,82	-22,99	13,29	38,58	19,04	-2,40	1,68	1,99	1,30	0,07	-3,76	-1,95	4,24
Moju	3,16	114,09	13016,53	1485056	0,15	0,16	26	2,39	1,64	14,23	-16,49	0,72	2,60	-9,96	6,43	63,19	42,06	15,39	8,31	-1,53	9,73	0,05	-16,82	0,39	-9,50
Monte Alegre	2,34	50,04	2504	125300,20	0,12	-0,01	2	1,59	1,79	15,68	-23,59	1,39	1,21	-9,07	6,04	60,80	27,15	-13,62	3	-2,14	-7,80	0,19	-0,16	3,21	-3,23
Muaná	1,98	64,03	4099,84	262512,80	0,20	0,06	1	2,96	0,89	15,61	-26,37	-0,15	3,88	-4,48	3,52	27,41	32,57	37,57	0,42	-0,02	4,20	0,62	-9,96	-0,67	0,19
Nova Esperança do Piriá	2,54	-8,15	66,42	-541,34	0,19	0,02	5	2,82	2,43	17,77	-24,02	1,31	4,39	-12,87	8,18	79,92	44,93	88,90	0,79	0,32	-3,73	0	-14,99	11,91	-15,4
Nova Ipixuna	2,18	55,79	3112,52	173647,70	0,15	0,03	13	2,08	2,06	14,90	-28,03	1,43	2,93	-15,33	9,27	67,80	37,38	64,59	1,22	-1,08	-6,93	0,53	-2,70	5,10	-13,41
Nova Timboteua	1,75	78,64	6184,25	486329,40	0,14	0,12	0	2,18	0,68	12,82	-25,72	1,48	6,37	-9,95	6,55	59,89	17,66	60,01	-3,10	-1,33	-6,80	0,11	0,10	1,27	7,27
Novo Progresso	3,55	180,84	32703,11	5914030	0,21	0	17	2,09	3,90	27,96	-21,60	0,98	1,39	-20,80	12,49	66,56	39,29	2,48	4,48	2,80	-9,23	-7,38	-4,02	9,79	-11,15
Novo Repartimento	3,59	76,97	5924,38	455999,60	0,17	-0,09	11	1,72	1,96	14,76	-17,55	1,21	4,33	-4,05	3,32	65,14	43,62	65,73	6,22	-2,71	-12,48	-0,07	0,13	6,26	-4,17
Óbidos	2,56	92,88	8626,69	801247,40	0,14	0,16	2	2,30	1,21	14,23	-30,62	1,17	2,72	-15,81	9,27	37,39	13,77	39,70	0,04	0,85	-7,95	0,42	-1,32	1,19	-1,59
Oeiras do Para	2,52	41,50	1722,25	71473,38	0,15	0,08	2	2,27	2,10	11,37	-23,25	0,49	2,92	-9,57	6,26	38,11	37,56	26,48	4,43	1,98	-19,05	-0,06	4,05	1,58	-0,68
Oriximiná	2,49	67,60	4569,76	308915,80	0,11	0,14	1	2,15	2,90	13,22	-22,66	0,75	2,66	-10,32	6,62	21,19	12,06	7,98	-3,67	2,38	2,39	-0,53	-2,30	-3,40	-1,91
Ourem	2	110,45	12199,20	1347402	0,13	0,12	1	2,27	1,28	15,74	-17,01	1,31	1,24	-8,79	5,97	60,06	20,08	5,63	1,34	-9,46	-4,12	-0,28	-2,30	-5,95	0,33
Ourilândia do Norte	2,54	153,76	23642,14	3635215	0,19	-0,04	17	1,26	3,23	25,24	-27,55	0,56	4,15	-4,96	3,69	70,75	33,42	43,74	35,67	-3,02	-31,68	4,62	-0,89	1,13	-13,01
Pacajá	3,53	-10,61	112,57	-1194,39	0,18	-0,13	21	1,78	1,94	16,91	-27,81	1,16	2,08	-12,88	8,43	70,67	40,92	35,18	7,16	-1,47	-15,87	-0,05	0,63	1,17	-22,74
Palestina do Para	2,10	52,10	2714,41	141420,80	0,13	-0,20	-1	1,66	1,31	13,91	-23,91	1,48	2,66	-7,51	5,14	75,83	29,98	57,31	7,92	4,33	-13,04	0,28	-2,39	6,58	-14,91
Paragominas	3,14	172,38	29714,86	5122248	0,17	0,04	30	2,10	3,64	21,21	-25,75	0,88	5,81	-9,23	6,11	48,80	6,06	8,19	8,36	-0,56	-5,40	4,36	-14,12	4,01	1,13
Parauapebas	2,26	182,64	33357,37	6092390	0,16	-0,23	65	1,15	3,65	26,88	-26,34	0,24	4,98	-17,76	11,8	40,94	4,65	9,19	22,19	-3,68	-8,92	1,42	-3,90	-4,25	-2,41
Pau D Arco	2,10	105,84	11202,11	1185631	0,17	0,07	3	2,91	3,46	20,08	-29,49	1,98	2,02	-14,88	9,7	60,99	31,51	71,92	16,76	7,10	-23,76	0,16	-0,98	13,19	4,72
Peixe Boi	1,72	72,26	5221,50	377306,10	0,14	0	0	2,04	1,40	13,83	-33,22	1,48	5,51	-7,37	5,05	61,28	28,04	32,05	1,67	-2,61	-9,82	0,08	-0,64	0,32	2,49
Piçarra	2,59	27,60	761,76	21024,58	0,19	-0,03	4	3,04	2,47	17,99	-20,09	1,70	4,13	-19,74	11,34	73,65	44,72	62,30	14,99	5,21	-20,66	0	-0,61	13,55	-18,57
Placas	2,72	14,28	203,91	2911,95	0,16	-0,02	0	2,39	1,34	16,34	-19,93	0,82	3,33	-12,97	8,43	64,37	40,18	62,26	2,67	3,50	-20,10	0,06	-0,43	13,83	-9,08
Ponta de Pedras	1,71	90,95	8271,90	752329,50	0,12	0,12	0	1,76	2,17	12,30	-12,65	-0,07	3,75	-11,13	7,23	34,45	22,99	45,32	1,99	-1,31	4,09	-0,76	-4,21	-3,11	-10,02
Portel	3,01	12,07	145,68	1758,41	0,12	-0,03	2	2,33	2,63	11,49	-19,49	0,15	3,19	-12,47	7,97	40	18,96	39,62	-0,72	0,56	1,38	-0,11	-16,25	1,81	5,52
Porto de Moz	2,89	25,21	635,54	16022,07	0,14	0	0	2,08	3,55	13,12	-15,12	0,55	4,28	-10,83	7,01	33,96	23,02	-15,99	-1,32	-1,16	-8,42	0	-5,32	2,70	-8,12
Prainha	2,91	72,31	5228,73	378089,90	0,16	0,31	-1	2,32	2,81	13,68	-16,15	1,21	6,40	-14,40	8,93	50,61	21,71	32,57	1,66	0,76	-3,21	0,06	-5,98	3,33	-12,29
Primavera	1,62	123,88	15346,25	1901094	0,15	0,24	0	1,53	1,14	14,22	-25,84	1,40	4,46	-21,58	12,69	62,28	15,49	45,67	-0,66	-7,65	-6,92	0,30	-0,35	-4,96	1,58
Quatipuru	1,35	105,29	11085,98	1167243	0,14	0,21	0	1,26	1,92	16,33	-25,71	1,15	4,17	-14,98	9,26	60,17	17,08	76,04	1,12	1,90	-15,23	-0,01	1,39	1,28	4,10
Redenção	2,16	125,35	15712,62	1969577	0,14	-0,11	45	1,73	3,90	20,03	-29,52	1,47	3,95	-15,54	9,02	46,28	3,83	17,14	11,54	-2,51	-5,44	0,17	-7,90	-0,13	-2,43
Rio Maria	2,53	75,29	5668,58	426787,70	0,14	-0,16	4	2,06	2,86	16,41	-23,33	1,72	4,82	-11,94	7,95	52,28	15,26	19,44	21,57	2,76	-12,54	2,35	-0,39	4,19	-13,6
Rondon do Pará	3,10	32,61	1063,41	34677,87	0,14	-0,09	10	1,63	2,61	13,83	-20,63	1,18	5,51	-14,67	9,48	48,49	6,71	11,51	0,95	-0,98	1,71	0,37	-9,34	-1,48	0,59
Rurópolis	2,59	11,28	127,23	1435,24	0,13	-0,11	1	0,60	2,44	13,75	-22,27	0,45	5,99	-17,82	10,97	64,32	22,30	55,56	2,23	2,39	-9,07	0,33	-0,98	5,09	-1,84

Salinópolis	1,34	86,46	7475,33	646317,20	0,13	-0,19	3	2,44	2	17,76	-14,46	1,21	2,37	-20,99	12,12	42,13	4,44	45,71	-2,72	0,79	-0,91	0	-0,98	-6,27	-1,35
Salvaterra	1,89	100,23	10046,05	1006916	0,13	0,06	2	2,50	1,87	18,53	-24,79	0,37	2,89	-7,37	5,28	68,50	23,12	25,20	0,06	-0,50	-9,80	0	-2,96	7	2,71
Santa Bárbara do Pará	1,54	88,38	7811,02	690338,30	0,12	0,07	2	0,75	0,85	14,96	-24,42	0,83	6,93	-9,02	6,24	48,56	2,42	5,85	0,90	-4,99	2,19	-0,18	-5,79	-3,64	6,93
Santa Cruz do Arari	-	5,24	27,45	143,87	0,16	-0,09	0	3,47	1,48	22,63	-17,75	0,32	6,64	-23,26	13,59	30,77	22,06	73,55	-9,15	-14,31	24,92	0	-6,53	-16,11	4,22
Santa Isabel do Pará	1,93	138,15	19085,42	2636651	0,12	-0,04	11	1,20	1,85	13,99	-36,61	0,68	3,93	-22,89	13,2	38,41	3,76	19,54	5,70	-0,31	-0,83	-1,32	3,23	-6,93	-1,63
Santa Luzia do Pará	1,67	91,87	8440,09	775391,70	0,18	0,04	3	2,23	1,43	15,14	-21,18	1,51	5,19	-12,09	8	68,80	29,12	7,08	2,72	-4,37	-15,09	0,25	-0,59	6,38	-1,67
Santa Maria das Barreiras	3,25	10,41	108,36	1128,11	0,14	0	0	2,42	2,34	13,86	-32,58	1,52	3,31	-20,15	10,93	71,62	31,85	30,56	5,84	-1,03	-15,23	0,14	-1,73	4,56	-0,48
Santa Maria do Para	1,94	77,48	6003,15	465124,10	0,14	-0,05	0	1,83	1,43	11,57	-17,75	1,31	5,98	-10,69	7,07	48,48	16,47	22,50	4,17	-2,63	5,02	0	-6,89	-4,82	-2,38
Santana do Araguaia	3,39	80,35	6456,12	518749,40	0,15	-0,18	19	1,75	2,75	23,62	-17,93	0,85	1,63	-20,99	12,12	64,23	26,52	17,81	16,51	1,30	-6,18	0,26	0,73	-1,20	-5,95
Santarém	2,91	18,49	341,88	6321,36	0,16	-0,13	5	2,85	0,84	22,90	-28,21	1,24	6,55	-5,62	4,20	65,34	13,70	66,80	0,72	-3,62	-0,58	0	-10,39	6,94	-19,39
Santarém Novo	1,73	130,06	16915,60	2200043	0,14	-0,03	0	1,76	4,29	17,60	-38,26	0,95	3,16	-22,59	13,06	31,32	11,74	25,06	6,23	-1,99	-3,84	-0,21	-5,49	1,46	-3,05
Santo Antônio do Tauá	1,82	158,09	24992,45	3951056	0,16	0,09	9	3,02	1,93	19,99	-21,53	0,86	1,24	-9,09	6,56	51,81	18,75	13,75	0,10	-6,18	-9,75	-0,26	-2,17	2,57	9,63
São Caetano de Odivelas	1,82	64,81	4200,33	272223,80	0,12	0,06	1	2,87	0,48	13,45	-27,30	1,59	1,52	-4,79	3,63	60,40	23,21	89,71	1,96	6,91	1,24	-0,25	0,17	-4,79	8,66
São Domingos do Araguaia	2,23	175,95	30958,40	5447131	0,14	0,07	10	1,86	2,10	20,30	-22,41	2,25	1,51	-5,48	4,05	80,92	24,42	47,70	3,89	-3,60	-8,05	0,27	-0,85	1,24	-0,70
São Domingos do Capim	2,35	1,78	3,16	5,63	0,16	0,15	10	2,65	2,52	16,19	-32,77	1,08	3,94	-5,79	4,16	44,55	36,71	2,89	1,47	-1,16	42,95	-0,10	-52,18	6,25	-1,49
São Felix do Xingu	4	-72,54	5262,05	-381709	0,16	-0,31	-2	1,45	1,47	23,29	-29,14	0,12	3,41	-13,10	8,30	75,47	37,85	20,10	18,04	-1,93	-11,43	-0,06	-3,23	4,44	-10,59
São Francisco do Para	1,88	30,97	959,14	29704,59	0,13	-0,26	3	2,23	0,72	15,33	-20,58	1,92	5,24	-10,48	7,09	46,53	14,39	7,96	5,34	-1,99	0,21	0,16	-8,28	1,06	7,15
São Geraldo do Araguaia	2,31	55,08	3033,80	167102,10	0,18	-0,19	16	2,35	4,01	19,03	-23,74	1,64	2,65	-17,08	10,52	68,76	36,56	51,28	11,46	-1,41	-19,92	0,12	-2,84	8,14	-12,98
São João da Ponta	1,50	50,71	2571,50	130401	0,14	-0,29	1	2,52	1,26	19,11	-27,65	0,76	4,20	-8,33	5,82	68,63	7,83	49,46	4,22	-0,98	24,72	0	-20,75	-0,54	-4,99
São João de Pirabas	1,91	65,69	4315,17	283463,90	0,12	0,05	0	1,81	0,71	11,80	-23,02	1,24	1,77	-14,22	8,83	65,28	17,72	56,93	-0,11	-3,13	-3,39	0	-0,51	-4,40	5,87
São João do Araguaia	2,37	87,08	7582,92	660321,20	0,20	-0,05	1	2,41	1,85	17,85	-22,78	1,62	6,25	-6,47	4,57	68,09	33,88	55,68	5,96	-2,81	-9,43	0,40	-3,01	0,16	-2,44
São Miguel do Guamá	2,31	54,47	2966,98	161611,40	0,14	-0,09	12	1,56	2,14	14,62	-36,79	0,83	4,97	-23,55	12,82	46,93	25,65	36,55	2,43	3,18	-6,47	-0,54	4,81	2,88	-0,19
São Sebastiao da Boa Vista	2,09	68,58	4703,21	322546,60	0,14	0,10	-1	1,50	1,39	16,63	-22,83	0,66	2,77	-17,76	10,36	24,15	27,98	58,78	1,85	-8,43	15,57	0	-8,67	-12,71	0,41
Sapucaia	1,31	91,35	8344,82	762299,50	0,12	0,12	1	1,23	2,11	13,45	-23,68	1,27	3,24	-9,63	6,31	54,16	3,99	53,94	9,92	1	-0,27	0,04	-1,43	-5,90	1,98
Senador José Porfírio	2,71	26,19	685,91	17964,14	0,15	-0,06	0	2,55	2,03	11,63	-20,89	0,93	3,47	-10,14	6,86	62,35	22,28	11,81	-2,45	-1,59	-10,68	4,26	0,09	3,45	-1,44
Soure	1,19	76,67	5878,28	450688,40	0,10	-0,13	0	1,55	3,13	13,04	-19,91	0,56	2,33	-12,12	7,60	53,63	13,59	53,96	1,24	-8,69	2,04	-0,08	-3,94	-9,26	7,27
Tailândia	2,86	-4,02	16,16	-64,96	0,16	-0,12	74	2,34	0,50	24,05	-23,13	0,63	1,76	-8,14	5,54	73,63	12,66	50,25	12,19	-1,98	-2,20	0,29	-12,98	3,05	-1,18
Terra Alta	1,64	58,69	3444,51	202158,60	0,13	-0,07	1	1,63	1,72	17,18	-27,02	1,42	2,07	-6,09	4,42	66	11,77	44,35	1	1,92	-12,79	0	-1,26	1,16	-11,92
Terra Santa	1,74	184,33	33977,55	6263082	0,15	0,16	1	2,10	2,55	16,56	-21,53	0,51	2,52	-7,65	5,15	58,62	17,89	33,38	3,67	-3,76	-13,42	1,09	-3,56	-0,15	3
Tome Açu	2,70	43,95	1931,60	84893,93	0,15	-0,08	22	3,03	1,52	15,14	-21,93	1,37	6,74	-8,74	5,84	40,83	17,15	32,30	2,47	-0,30	-2,24	0,68	-3,88	-1,48	-4,51
Tracuateua	1,21	80,75	6520,56	526535,40	0,17	0,06	1	2,38	0,93	16,20	-21,83	0,68	6,42	-21,64	13,04	63,59	46,36	54,22	2,53	0,28	-7,46	-0,19	-1,63	3,47	-24,23
Trairão	2,70	109,13	11909,36	1299668	0,17	0,15	0	1,63	1,80	16,05	-29,01	1,24	4,34	-21,91	12,78	69,80	34,53	70,85	6,05	1,96	-11,93	0,60	-3,98	8,91	-10,16
Tucumã	2,48	20,15	406,02	8181,35	0,15	-0,25	14	0,63	2,34	22,54	-20,23	1,36	4,26	-14,95	9,13	59,26	28,08	24,72	18,78	-1,43	-14,41	3,60	-0,36	-5,18	-10,77
Tucuruí	2,28	179,41	32187,95	5774840	0,12	0,02	71	0,94	3,26	15,73	-24,65	0,78	2,53	-12,44	8,36	40,56	2,34	11,17	-3,41	-1,54	2,30	0	-0,03	-0,63	2,31
Ulianópolis	3,01	52,4	2745,76	143877,80	0,18	-0,11	8	1,36	0,43	20,87	-15,34	1,09	4,99	-8,10	5,48	62,07	11,08	73,52	23,75	0,95	-0,37	-0,08	2,01	1,72	-8,50
Uruará	3,31	-56,92	3239,88	-184414	0,14	0,01	10	1,76	1,45	17,72	-26,75	1,15	3,87	-17,45	10,34	63,51	38,81	31,56	7,61	2,08	-15,29	-0,03	0,04	7,53	-15,93
Vigia	1,73	78,19	6113,67	478028,30	0,13	-0,16	14	1,37	2,79	13,67	-10,25	0,96	1,16	-11,90	7,89	43,98	9,27	27,15	5,04	-1,98	1,71	-0,15	-3,38	-3,34	4,75
Viseu	2,50	47,79	2283,88	109146,80	0,16	0,18	1	2,33	1,79	15,39	-19,59	0,37	5,44	-4,33	3,42	63,28	39,99	32,55	2,46	1,62	-10,44	0,01	-0,91	6,67	-13,74
Vitória do Xingu	2,95	61,77	3815,53	235685,50	0,17	-0,01	4	3,11	1,51	14,83	-26,89	0,66	4,79	-18,24	10,98	63,08	32,22	-18,83	0,41	-2,11	-4,60	-0,17	-5,79	-1,17	-1,32
Xinguara	2,35	77,35	5983,02	462786,80	0,13	-0,08	1	0,82	3,62	17,54	-23,11	0,93	3,74	-15,11	9,60	52,59	11,10	58,66	19,01	-1,16	-10,76	-0,20	1,51	-1,15	-7,45

Appendix 2

Geographically Weighted Regression (GWR) R-code for EKC analysis.

```
require (spgwr)
require (ggplot2)
require (maptools)
Data Table <- read.csv ("data.csv")
attach (Data Table)
View (Data Table)

#Calculate Kernel bandwidth

GWRbandwidth <- gwr.sel (X variable ~ Y variable, data = Data Table, coords = cbind (X coordinate, Y coordinate), adapt = T)

#Run the GWR model

gwr.model = gwr (X variable ~ Y variable, data = Data Table, coords = cbind (X coordinate, Y coordinate), adapt = GWRbandwidth, hatmatrix = TRUE, se.fit = TRUE)

#Print the results of the model

gwr.model
Results <- as.data.frame (gwr.model$SDF)
head (Results)

#Save the preliminary results

write.csv (Results, "results.csv", row.names = FALSE)

#Attach coefficients to original dataframe

Data Table$Coef <- Results$coefbeta
Data Table$Coef_se <- Results$coefbeta_se
Data Table$Intercept <- Results$X.Intercept.
Data Table$Intercept_se <- Results$X.Intercept._se
Data Table$residuals <- Results$gwr.e
Data Table$LocalR2 <- Results$localR2

#Save the results

write.csv (Data Table, "resultsGWR.csv", row.names = FALSE)
```

Appendix 3

Table A3.1 - Main statistical results from GWR for EKC analysis.

MUNICIPALITIES	DINC β_1	$DINC^2$ β_2	$DINC^3$ β_3	β_1 St. Error	β_2 St. Error	β_3 St. Error	β_1 Tstats.	β_2 Tstats.	β_3 Tstats.	Local R^2
Abel Figueiredo	-0,008470	0,000071	0	0,002338	0,000034	0	-3,622704	2,099588	-1,724657	0,481136
Afuá	-0,008247	0,000061	0	0,002628	0,000039	0	-3,138205	1,586185	-1,062617	0,481224
Água Azul do Norte	-0,008190	0,000067	0	0,002250	0,000033	0	-3,639176	2,026279	-1,583278	0,466288
Alenquer	-0,008333	0,000071	0	0,002248	0,000033	0	-3,707553	2,178212	-1,620334	0,462265
Almeirim	-0,008258	0,000070	0	0,002299	0,000033	0	-3,591694	2,115056	-1,625618	0,465534
Altamira	-0,008095	0,000072	0	0,002259	0,000033	0	-3,583205	2,191568	-1,765991	0,456432
Anajás	-0,008023	0,000057	0	0,002985	0,000043	0	-2,687593	1,312009	-0,839338	0,478113
Anapu	-0,008102	0,000072	0	0,002250	0,000033	0	-3,601215	2,218775	-1,828408	0,463243
Aveiro	-0,008246	0,000071	0	0,002236	0,000033	0	-3,688441	2,170140	-1,620950	0,457299
Bagre	-0,008058	0,000062	0	0,002646	0,000038	0	-3,045542	1,618018	-1,166758	0,477854
Baião	-0,008183	0,000067	0	0,002571	0,000037	0	-3,182280	1,817960	-1,409142	0,482030
Bannach	-0,008204	0,000066	0	0,002249	0,000033	0	-3,648222	2,006862	-1,547588	0,468868
Belterra	-0,008296	0,000071	0	0,002241	0,000033	0	-3,701488	2,178466	-1,625097	0,460129
Bom Jesus do Tocantins	-0,008451	0,000071	0	0,002327	0,000034	0	-3,631847	2,108717	-1,739235	0,476899
Brasil Novo	-0,008060	0,000072	0	0,002265	0,000033	0	-3,558962	2,187217	-1,764117	0,450781
Brejo Grande do Araguaia	-0,008428	0,000069	0	0,002309	0,000034	0	-3,650523	2,062433	-1,676883	0,478512
Breu Branco	-0,008338	0,000073	0	0,002326	0,000034	0	-3,585214	2,168443	-1,786826	0,473653
Breves	-0,008095	0,000064	0	0,002533	0,000037	0	-3,196235	1,719595	-1,258181	0,478405
Cametá	-0,007862	0,000059	0	0,003156	0,000044	0	-2,490898	1,325689	-0,949569	0,485944
Canaã dos Carajás	-0,008244	0,000067	0	0,002260	0,000033	0	-3,647851	2,032313	-1,606582	0,469602
Chaves	-0,008136	0,000057	0	0,002926	0,000042	0	-2,781111	1,353507	-0,852585	0,476552
Conceição do Araguaia	-0,008302	0,000066	0	0,002242	0,000033	0	-3,703670	2,003629	-1,515474	0,479948

Cumaru do Norte	-0,008163	0,000066	0	0,002252	0,000033	0	-3,625739	1,984672	-1,520847	0,465791
Curionópolis	-0,008276	0,000068	0	0,002266	0,000033	0	-3,652009	2,057433	-1,650085	0,470201
Curralinho	-0,007946	0,000058	0	0,002985	0,000043	0	-2,662190	1,358089	-0,927044	0,482113
Curuá	-0,008351	0,000071	0	0,002242	0,000033	0	-3,724412	2,180530	-1,611712	0,463673
Dom Eliseu	-0,008394	0,000070	0	0,002619	0,000037	0	-3,204405	1,888465	-1,561836	0,495521
Eldorado dos Carajás	-0,008306	0,000068	0	0,002267	0,000033	0	-3,664262	2,057695	-1,646351	0,473072
Faro	-0,008377	0,000071	0	0,002225	0,000033	0	-3,765488	2,181859	-1,587689	0,467682
Floresta do Araguaia	-0,008273	0,000066	0	0,002245	0,000033	0	-3,684887	2,011384	-1,540262	0,476014
Goianésia do Pará	-0,008402	0,000073	0	0,002423	0,000035	0	-3,468053	2,088100	-1,719264	0,477548
Gurupá	-0,008203	0,000068	0	0,002345	0,000034	0	-3,498202	2,015982	-1,548756	0,472550
Itaituba	-0,008231	0,000071	0	0,002232	0,000033	0	-3,688408	2,160410	-1,605375	0,457119
Itupiranga	-0,008351	0,000071	0	0,002285	0,000033	0	-3,655085	2,138248	-1,768930	0,469433
Jacareacanga	-0,008242	0,000070	0	0,002220	0,000033	0	-3,712348	2,137059	-1,563885	0,462245
Jacundá	-0,008412	0,000072	0	0,002308	0,000033	0	-3,645445	2,165213	-1,789346	0,475901
Juruti	-0,008362	0,000071	0	0,002231	0,000033	0	-3,749061	2,182021	-1,597444	0,465667
Marabá	-0,008365	0,000070	0	0,002283	0,000033	0	-3,664418	2,112579	-1,730803	0,472997
Medicilândia	-0,008082	0,000072	0	0,002258	0,000033	0	-3,578833	2,183988	-1,739747	0,449623
Melgaço	-0,008096	0,000066	0	0,002446	0,000036	0	-3,309365	1,841126	-1,392782	0,476725
Mocajuba	-0,008067	0,000064	0	0,002833	0,000040	0	-2,847675	1,584263	-1,195175	0,485482
Monte Alegre	-0,008296	0,000072	0	0,002260	0,000033	0	-3,670546	2,171085	-1,637455	0,459971
Nova Ipixuna	-0,008399	0,000072	0	0,002299	0,000033	0	-3,654167	2,145118	-1,775762	0,472608
Novo Progresso	-0,008083	0,000069	0	0,002233	0,000033	0	-3,618957	2,087829	-1,563417	0,451178
Novo Repartimento	-0,008259	0,000074	0	0,002275	0,000033	0	-3,630600	2,238000	-1,887585	0,461919
Óbidos	-0,008356	0,000071	0	0,002239	0,000033	0	-3,732270	2,181495	-1,606232	0,464072
Oeiras do Pará	-0,008007	0,000060	0	0,002848	0,000041	0	-2,811608	1,471660	-1,038863	0,481753
Oriximiná	-0,008372	0,000071	0	0,002235	0,000033	0	-3,745232	2,182683	-1,599274	0,465505
Ourilândia do Norte	-0,008115	0,000067	0	0,002252	0,000033	0	-3,603091	2,024664	-1,587808	0,459027
Pacajá	-0,008135	0,000073	0	0,002250	0,000033	0	-3,614710	2,242962	-1,878174	0,462765

Palestina do Pará	-0,008433	0,000069	0	0,002311	0,000034	0	-3,649357	2,057431	-1,670929	0,479202
Parauapebas	-0,008235	0,000068	0	0,002266	0,000033	0	-3,634204	2,058189	-1,656446	0,466233
Pau D'Arco	-0,008241	0,000066	0	0,002246	0,000033	0	-3,669476	1,999672	-1,526058	0,473331
Piçarra	-0,008351	0,000067	0	0,002263	0,000033	0	-3,690132	2,041757	-1,608429	0,479631
Placas	-0,008151	0,000072	0	0,002245	0,000033	0	-3,631150	2,167512	-1,661236	0,450348
Portel	-0,008109	0,000067	0	0,002398	0,000035	0	-3,382152	1,919289	-1,476908	0,476272
porto de Moz	-0,008214	0,000070	0	0,002304	0,000033	0	-3,564670	2,105843	-1,636589	0,466191
Prainha	-0,008276	0,000071	0	0,002276	0,000033	0	-3,636326	2,156272	-1,643469	0,460263
Redenção	-0,008248	0,000066	0	0,002243	0,000033	0	-3,676617	2,000051	-1,519805	0,474341
Rio Maria	-0,008236	0,000066	0	0,002249	0,000033	0	-3,661839	2,009764	-1,550769	0,471814
Rondon do Pará	-0,008486	0,000071	0	0,002379	0,000034	0	-3,566596	2,068485	-1,695164	0,486423
Rurópolis	-0,008178	0,000071	0	0,002239	0,000033	0	-3,651876	2,161995	-1,634413	0,452306
Santa Maria das Barreiras	-0,008289	0,000066	0	0,002233	0,000033	0	-3,712086	2,008407	-1,502426	0,479401
Santana do Araguaia	-0,008260	0,000066	0	0,002231	0,000033	0	-3,701653	2,004353	-1,492231	0,476823
Santarém	-0,008300	0,000071	0	0,002245	0,000033	0	-3,696747	2,178368	-1,628513	0,460199
São Domingos do Araguaia	-0,008405	0,000070	0	0,002298	0,000033	0	-3,657094	2,083214	-1,699586	0,476183
São Felix do Xingu	-0,008024	0,000068	0	0,002250	0,000033	0	-3,566663	2,034616	-1,594255	0,450153
São Geraldo do Araguaia	-0,008377	0,000067	0	0,002274	0,000033	0	-3,684189	2,037266	-1,612475	0,480869
São João do Araguaia	-0,008409	0,000070	0	0,002302	0,000033	0	-3,653758	2,099189	-1,721864	0,475180
São Sebastião da Boa Vista	-0,007634	0,000053	0	0,003502	0,000049	0	-2,179741	1,083473	-0,704633	0,482068
Sapucaia	-0,008267	0,000067	0	0,002252	0,000033	0	-3,670512	2,022447	-1,573896	0,473719
Senador José Porfírio	-0,008162	0,000071	0	0,002272	0,000033	0	-3,592133	2,160768	-1,716723	0,464840
Tailândia	-0,007921	0,000063	0	0,003280	0,000045	0	-2,414656	1,409639	-1,123613	0,491313
Terra Santa	-0,008374	0,000071	0	0,002227	0,000033	0	-3,759935	2,182268	-1,591173	0,466987

Trairão	-0,008209	0,000071	0	0,002231	0,000033	0	-3,679359	2,152884	-1,601764	0,456089
Tucumã	-0,008101	0,000067	0	0,002254	0,000033	0	-3,593975	2,020742	-1,586905	0,457700
Tucuruí	-0,008321	0,000073	0	0,002310	0,000033	0	-3,602295	2,180377	-1,797192	0,473250
Ulianópolis	-0,007977	0,000065	0	0,003232	0,000044	0	-2,468031	1,493435	-1,274002	0,502883
Uruará	-0,008123	0,000072	0	0,002250	0,000033	0	-3,610069	2,172240	-1,686838	0,448852
Vitória do Xingu	-0,008155	0,000071	0	0,002260	0,000033	0	-3,608440	2,180608	-1,738204	0,463068
Xinguara	-0,008246	0,000066	0	0,002250	0,000033	0	-3,664919	2,017256	-1,563415	0,472267

Appendix 4

Table A4.1 - Main statistical results from GWR for difference in the percentage of employees with a formal contract (DPEFC) in the EKC analysis.

MUNICIPALITIES	β DPEFC	β St. Error	β Tstats.*
Abaetetuba	0,040952	0,014506	2,823087
Acará	0,041594	0,015324	2,714296
Afuá	0,029666	0,010793	2,748692
Alenquer	0,021248	0,009032	2,352657
Almeirim	0,021173	0,009165	2,310219
Anajás	0,031968	0,011901	2,686152
Ananindeua	0,038946	0,016628	2,342185
Augusto Correa	0,039965	0,015690	2,547187
Aurora do Pará	0,041938	0,015012	2,793597
Aveiro	0,020134	0,009029	2,229899
Bagre	0,024737	0,010784	2,293895
Baião	0,020170	0,010228	1,972060
Barcarena	0,041184	0,015686	2,625490
Belém	0,040614	0,015862	2,560522
Belterra	0,020724	0,009024	2,296656
Benevides	0,037646	0,016963	2,219308
Bonito	0,035110	0,017392	2,018730
Bragança	0,039146	0,016087	2,433356
Breves	0,024218	0,010374	2,334438
Bujaru	0,034774	0,017639	1,971474
Cachoeira do Arari	0,040536	0,015670	2,586840
Cachoeira do Piriá	0,041852	0,014495	2,887419
Cametá	0,027792	0,011369	2,444539
Capanema	0,035169	0,017529	2,006300
Capitão Poço	0,039532	0,015915	2,483928
Chaves	0,032868	0,011825	2,779612
Colares	0,037715	0,017041	2,213174
Concórdia do Pará	0,041414	0,015159	2,731904
Conceição do Araguaia	0,018000	0,009010	1,997760
Curralinho	0,028937	0,011504	2,515385
Curuá	0,021448	0,009005	2,381687
Dom Eliseu	0,020114	0,009827	2,046836
Faro	0,021763	0,008917	2,440536
Garrafão do Norte	0,041614	0,015148	2,747206
Gurupá	0,021941	0,009362	2,343584
Igarapé-Mirim	0,038019	0,013297	2,859216
Ipixuna do Pará	0,040499	0,013431	3,015351
Irituia	0,036261	0,016737	2,166519
Itaituba	0,020074	0,009023	2,224811
Jacareacanga	0,020320	0,008942	2,272369
Juruti	0,021582	0,008952	2,410745
Limoeiro do Ajuru	0,034068	0,012669	2,689160
Mãe do Rio	0,041014	0,015308	2,679168
Maracanã	0,035263	0,017640	1,999045
Marapanim	0,036101	0,017369	2,078479

Marituba	0,038369	0,016847	2,277514
Melgaço	0,022425	0,009969	2,249557
Mocajuba	0,023509	0,010695	2,198075
Moju	0,041106	0,014288	2,876882
Monte alegre	0,020871	0,009084	2,297639
Muaná	0,038945	0,014089	2,764251
Nova Esperança	0,042076	0,014036	2,997624
Novo progresso	0,018159	0,009082	1,999466
Óbidos	0,021535	0,008995	2,394225
Oeiras do Pará	0,026651	0,011147	2,390846
Oriximiná	0,021732	0,008974	2,421786
Ourém	0,038187	0,016337	2,337391
Paragominas	0,032954	0,011778	2,797965
Placas	0,018727	0,009102	2,057508
Ponta de Pedras	0,041190	0,015422	2,670860
Portel	0,021365	0,009722	2,197539
Porto de Moz	0,020712	0,009176	2,257212
Prainha	0,020841	0,009126	2,283584
Primavera	0,036917	0,016946	2,178468
Quatipuru	0,038170	0,016458	2,319305
Rurópolis	0,019263	0,009081	2,121236
São Caetano de Odivelas	0,035180	0,017926	1,962557
São Domingos do Capim	0,035186	0,017108	2,056736
São João de Pirabas	0,036494	0,017172	2,125251
São Miguel do Guamá	0,036669	0,016659	2,201164
São Sebastião da Boa Vista	0,032953	0,012357	2,666771
Salinópolis	0,036501	0,017210	2,120965
Salvaterra	0,039111	0,016530	2,366064
Santa Bárbara do Pará	0,037354	0,017216	2,169757
Santa Isabel do Pará	0,036057	0,017473	2,063513
Santa Luzia do Pará	0,039331	0,016022	2,454776
Santa Maria das Barreiras	0,018379	0,008959	2,051427
Santana do Araguaia	0,018338	0,008957	2,047381
Santarém	0,020788	0,009035	2,300733
Senador José Porfírio	0,018606	0,009048	2,056283
Soure	0,039200	0,016450	2,382944
Tailândia	0,024238	0,010896	2,224471
Terra Santa	0,021724	0,008931	2,432371
Tomé-Açu	0,040488	0,013490	3,001259
Tracuateua	0,037850	0,016615	2,278023
Trairão	0,019807	0,009029	2,193797
Ulianópolis	0,023618	0,010447	2,260651
Uruará	0,018232	0,009120	1,999196
Vigia	0,035752	0,017756	2,013530
Viseu	0,040896	0,013978	2,925767
Vitória do Xingu	0,017974	0,009009	1,995163

* Significance to 5%.

Table A4.2 - Main statistical results from GWR for difference in the percentage of employees in the mineral extraction sector (DPEMES) in the EKC analysis.

MUNICIPALITIES	β DPEMES	β St. Error	β Tstats.*
Abaetetuba	0,174360	0,085475	2,039908
Acará	0,202008	0,094146	2,145683
Augusto Correa	0,205108	0,093775	2,187235
Aurora do Pará	0,214724	0,095024	2,259690
Barcarena	0,188920	0,093884	2,012284
Belém	0,190803	0,094920	2,010157
Bonito	0,204241	0,097112	2,103142
Bragança	0,205920	0,094830	2,171456
Cachoeira do Piriá	0,207451	0,091798	2,259859
Capanema	0,202445	0,097232	2,082082
Capitão Poço	0,217732	0,096707	2,251450
Concórdia do Pará	0,206092	0,094009	2,192254
Garrafão do Norte	0,217153	0,095413	2,275931
Igarapé-Mirim	0,152519	0,077220	1,975116
Ipixuna do Pará	0,188029	0,086314	2,178426
Irituia	0,213386	0,097210	2,195098
Mãe do Rio	0,215341	0,095638	2,251619
Moju	0,176737	0,085583	2,065093
Nova Esperança	0,204694	0,090734	2,255966
Nova Timboteua	0,194990	0,098675	1,976076
Ourém	0,212704	0,096427	2,205852
Paragominas	0,134933	0,068508	1,969602
Peixe-Boi	0,198354	0,097822	2,027707
Ponta de Pedras	0,181015	0,090607	1,997818
Primavera	0,199656	0,096142	2,076674
Quatipuru	0,200786	0,095109	2,111111
São Domingos do Capim	0,202122	0,096991	2,083926
São João de Pirabas	0,195715	0,096552	2,027048
São Miguel do Guamá	0,207869	0,096421	2,155851
Salinópolis	0,191426	0,096914	1,975222
Santa Luzia do Pará	0,214193	0,096134	2,228069
Santa Maria do Pará	0,194834	0,098514	1,977744
Tomé-Açu	0,181435	0,085169	2,130297
Tracuateua	0,205305	0,095851	2,141919
Viseu	0,190832	0,086280	2,211779

* Significance to 5%.

Table A4.3 - Main statistical results from GWR for difference in the percentage of employees in the service sector (DPESS) in the EKC analysis.

MUNICIPALITIES	β DPESS	β St. Error	β Tstats.*
Abel Figueiredo	0,034928	0,017177	2,033387
Água Azul do Norte	0,033617	0,016052	2,094205
Alenquer	0,031393	0,015653	2,005583
Aveiro	0,032193	0,015758	2,042935
Bannach	0,033760	0,015944	2,117406
Belterra	0,031709	0,015677	2,022602
Bom Jesus do Tocantins	0,034865	0,017200	2,027064
Brejo grande do Araguaia	0,034731	0,017008	2,041980
Breu Branco	0,034495	0,017104	2,016813
Canaã dos Carajás	0,033876	0,016274	2,081591
Conceição do Araguaia	0,034049	0,015804	2,154521
Cumaru do Norte	0,033793	0,015918	2,122914
Curionópolis	0,034027	0,016496	2,062767
Curuá	0,031658	0,015624	2,026188
Dom Eliseu	0,035303	0,017553	2,011264
Eldorado dos Carajás	0,034129	0,016499	2,068463
Faro	0,032552	0,015580	2,089352
Floresta do Araguaia	0,033937	0,015901	2,134233
Goianésia do Pará	0,035035	0,017315	2,023427
Itaituba	0,032680	0,015824	2,065207
Itupiranga	0,034436	0,016991	2,026733
Jacareacanga	0,033614	0,015842	2,121819
Jacundá	0,034720	0,017072	2,033734
Juruti	0,032266	0,015602	2,068112
Marabá	0,034461	0,016891	2,040187
Nova Ipixuna	0,034647	0,017084	2,028035
Novo Progresso	0,033539	0,016082	2,085561
Novo Repartimento	0,033962	0,017055	1,991264
Óbidos	0,031867	0,015621	2,039972
Oriximiná	0,032034	0,015601	2,053327
Ourilândia do Norte	0,033347	0,016069	2,075256
Pacajá	0,032785	0,016718	1,960982
Palestina do Pará	0,034745	0,017012	2,042405
Parauapebas	0,033871	0,016496	2,053319
Pau D'Arco	0,033911	0,015864	2,137643
Piçarra	0,034224	0,016359	2,092035
Placas	0,031516	0,015851	1,988294
Redenção	0,033933	0,015819	2,145032
Rio Maria	0,033846	0,015968	2,119574
Rondon do Pará	0,035047	0,017236	2,033304
Rurópolis	0,032071	0,015854	2,022890
São Domingos do Araguaia	0,034645	0,016968	2,041732
São Felix do Xingu	0,032945	0,016064	2,050800
São Geraldo do Araguaia	0,034376	0,016502	2,083066
São João do Araguaia	0,034681	0,017037	2,035641
Santa Maria das Barreiras	0,034030	0,015669	2,171887
Santana do Araguaia	0,034044	0,015636	2,177332
Santarém	0,031491	0,015677	2,008687
Sapucaia	0,033913	0,016086	2,108248
Tailândia	0,036076	0,018133	1,989544

* Significance to 5%.

Table A4.4 - Main statistical results from GWR for difference in the percentage of the population with garbage collection (DPPGC) in the EKC analysis.

MUNICIPALITIES	β DPPGC	β St. Error	β Tstats.*
Abel Figueiredo	-0,005092	0,002250	-2,263342
Água Azul do Norte	-0,006155	0,002162	-2,847445
Alenquer	-0,006001	0,002151	-2,789580
Almeirim	-0,005431	0,002198	-2,471183
Altamira	-0,005435	0,002195	-2,476583
Anapu	-0,005066	0,002193	-2,310392
Aveiro	-0,006230	0,002156	-2,890106
Bannach	-0,006298	0,002155	-2,922683
Belterra	-0,006093	0,002152	-2,831343
Bom Jesus do Tocantins	-0,005101	0,002252	-2,265497
Brasil Novo	-0,005528	0,002211	-2,500080
Brejo Grande do Araguaia	-0,005508	0,002230	-2,469975
Canaã dos Carajás	-0,006004	0,002174	-2,761989
Conceição do Araguaia	-0,006403	0,002134	-3,000240
Cumaru do Norte	-0,006417	0,002162	-2,967778
Curionópolis	-0,005796	0,002186	-2,651174
Curuá	-0,006056	0,002143	-2,825821
Dom Eliseu	-0,004773	0,002327	-2,051024
Eldorado dos Carajás	-0,005798	0,002184	-2,654961
Faro	-0,006242	0,002120	-2,944450
Floresta do Araguaia	-0,006305	0,002143	-2,942233
Gurupá	-0,005074	0,002232	-2,273842
Itaituba	-0,006352	0,002155	-2,947950
Itupiranga	-0,005176	0,002226	-2,325011
Jacareacanga	-0,006557	0,002135	-3,071585
Jacundá	-0,004795	0,002244	-2,137275
Juruti	-0,006188	0,002129	-2,906573
Marabá	-0,005351	0,002214	-2,416779
Medicilândia	-0,005679	0,002203	-2,577960
Melgaço	-0,004568	0,002317	-1,971498
Monte Alegre	-0,005873	0,002169	-2,707640
Nova Ipixuna	-0,005039	0,002238	-2,252038
Novo Progresso	-0,006602	0,002176	-3,033847
Novo Repartimento	-0,004618	0,002251	-2,051245
Óbidos	-0,006107	0,002140	-2,854257
Oriximiná	-0,006136	0,002133	-2,876245
Ourilândia do Norte	-0,006173	0,002174	-2,839881
Pacajá	-0,004821	0,002213	-2,178839
Palestina do Pará	-0,005528	0,002231	-2,478492
Parauapebas	-0,005788	0,002190	-2,642671
Pau D'Arco	-0,006377	0,002146	-2,972270
Piçarra	-0,005945	0,002170	-2,739580
Placas	-0,006091	0,002183	-2,790879
Portel	-0,004669	0,002288	-2,040507
Porto de Moz	-0,005325	0,002207	-2,413458
Prainha	-0,005709	0,002184	-2,613782
Redenção	-0,006409	0,002141	-2,993400

Rio Maria	-0,006267	0,002153	-2,911080
Rondon do Pará	-0,005030	0,002262	-2,223651
Rurópolis	-0,006229	0,002173	-2,866215
São Domingos do Araguaia	-0,005436	0,002224	-2,444132
São Felix do Xingu	-0,006234	0,002187	-2,851101
São Geraldo do Araguaia	-0,005895	0,002183	-2,699965
São João do Araguaia	-0,005314	0,002231	-2,382045
Santa Maria das Barreiras	-0,006493	0,002122	-3,059980
Santana do Araguaia	-0,006564	0,002122	-3,093975
Santarém	-0,006038	0,002155	-2,802119
Sapucaia	-0,006150	0,002157	-2,851158
Senador José Porfírio	-0,005309	0,002190	-2,424737
Terra Santa	-0,006219	0,002123	-2,928774
Trairão	-0,006394	0,002158	-2,963251
Tucumã	-0,006174	0,002179	-2,834030
Tucuruí	-0,004466	0,002262	-1,974230
Uruará	-0,005963	0,002192	-2,719890
Vitória do Xingu	-0,005371	0,002181	-2,462671
Xinguara	-0,006209	0,002154	-2,882124

* Significance to 5%.