LAND USE CHANGES AND SOCIOECONOMIC CONDITIONS OF COMMUNITIES ALONG THE CARAJÁS RAILROAD IN EASTERN AMAZONIA

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Abstract

Studies on communities along large railroad infrastructures are very relevant because their operations can present socioeconomic and environmental impacts. This article examines the socioeconomic and environmental conditions of 32 communities directly affected by the Carajás Railroad, located in Pará and Maranhão states, eastern Amazon. The study analyses land-use changes in the territory and the indicators of those dimensions from 2010 to 2017. The environmental dimension involved qualitative analysis of satellite images from Google Earth, whereas the socioeconomic examined 17 variables collected during fieldwork in 2016 and 2017. To compare the indicators between urban and rural communities, the statistical tests of Kolmogorov Smirnov normality, the parametric Student's t, and the non-parametric Mann-Whitney and Kruskal-Wallis were conducted, considering a 5% significance level. Overall, the results show urban communities are in better condition and that those on the Maranhão railroad side are in a less sustainable situation. The study also found that the community's location along the railroad is associated with the forms of land-use and occupation in the territory; and directly influences the living conditions of locals since, in the communities near the railroad, there was a higher variation in land cover and socioeconomic indicators. The joint analysis of socioeconomic data with satellite images, in defined periods, can subsidize actions aimed at reducing risk situations and increasing the resilience and communities' sustainability endeavors.

Keywords: communities, railroad, land use, sustainability, Amazon

1. Introduction

The technical-scientific-informational environment - a term created by Santos (1998) and translated as the third and current phase of the Industrial Revolution - has increasingly altered the geographical space when we focus our attention on the Eastern Amazon region, where mining directly influences demographic, economic, and environmental dynamics.

The mineral exploration in this region of the Brazilian Amazon, by the Vale S.A, involves a large mining and logistics complex, covering part of Pará and Maranhão states. The mine-rail-port system locates between the mines of the Carajás site, including the S11D mine, in Canaã dos Carajás municipality, Pará, and the Itaqui Port, in São Luís, Maranhão, interconnected by

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the approximately 1,000km of extension referring to the Carajás Railroad (named henceforward as EFC) and its branch.

The EFC's territory is composed of 28 municipalities, five and 23 in Pará and Maranhão states, respectively, in addition to hundreds of rural and urban communities located along this route (Fig. 1).

Figure 1 here

Despite the growing number of studies concerning the Amazon region, few focus on the EFC territory. Of these, for instance, Falesi et al. (1986) surveyed soils and agricultural aptitude; Coelho (1997) analyzed the economic and social development linked to mineral extraction using the concept of sustainable development; Corteletti (2014) presented a methodological proposal for the analysis of geological-geotechnical risks; Santos (2016) focused on the area of archeology in the region; Damasceno et al. (2017) examined the reuse of discarded wood waste for electricity generation.

However, there are requisite new studies focused on communities located alongside large railway structures, as is the EFC, which shows the relevance of this work in the subject. The railroad influences these communities more than the municipalities themselves or their headquarters since many are directly crossed by it or are very close to it. Santos et al. (2018) studied communities located along the railroad and analyzed the network of institutions that operate in them, demonstrating the importance of strengthening these networks and the stakeholders' actions.

This study examines the socio-economic and environmental conditions in communities directly influenced by the EFC railroad. Land use and the indicators changes in these dimensions on a 32-community sample for the 2010-2017 period are analyzed. Social and economic indicators are used, and qualitative analysis of satellite images is done. Since these communities are directly, or indirectly, influenced by this relevant logistical infrastructure, they are critical within the railroad and the Great Carajás Project. Primary and secondary data quantitative analysis was done, and we highlighted the demographic dynamics of these communities. The analysis period was conditioned by the data available on the scale of census tracts and field research in the biennium 2016-17. The census tract scale presents a limitation because the IBGE does not repeat them in all censuses; the latter makes a comparison between tracts of different censuses hard since they do not coincide; Therefore, the 2010 census was chosen due to its most current delimitation of these polygons, which is fundamental for analysis at the community level.

The research differs from others by analyzing communities that, in general, are not studied in a specific way, and by basing such a study on the analysis of satellite images of the EFC territory linked to the analysis of data at the scale of census tracts, besides working with primary data from field research. This approach assesses the socio-environmental conditions of the EFC communities over a period of almost a decade, which makes up for the absence of data after the last 2010 census and complements other studies on the railroad (Falesi et al., 1986; Coelho, 1997; Corteletti, 2014), focused on larger scales.

The EFC infrastructure transports 120 million tons of cargo - in 2016, it reached 155 million (PPI, 2018) - and 350 thousand passengers per year (Vale S.A., n.d.). EFC's region of influence has 2.4 million inhabitants and was responsible for about US$ 17 billion in GDP in 2016 (Santos et al., 2019). Except for São Luís, Marabá, Parauapebas, and Canaã dos Carajás municipalities, which are home to large companies, the territory has precarious socioeconomic indicators and suffers high environmental pressures (IBGE, 2010; ITV, 2017).

Therefore, to understand the living conditions of the populations living throughout the EFC, this research seeks to answer the following questions:

(1) Do these data reflect on the lives of the residents of the communities located in this territory?

(2) What are the land use and occupation conditions and their evolution in these communities from 2010 to 2017?

(3) Does this evolution reflect the social and economic indicators of the 2010 census and field research for the biennium 2016-17?

(4) Do urban communities have better conditions than rural ones?

The economic, social, and environmental importance of the Carajás Railroad, a corridor for the flow of mining production and circulation of people, justifies the need for research and studies on the dynamics of municipalities and communities of its territory.

This research tests the following hypotheses:

(1): The location of communities along the railroad is associated with types of land use and occupation in the territory

(2): Such a location directly influences the living conditions of locals

(3): The living conditions of the communities are the effect of the historical formation process of the municipalities of the Amazon region

This work allows the identification and understanding of why several communities have better conditions or the railroad influence them more than others; consequently, it will help establish targets for receiving actions and public or private policies in the region.

2. Theorethical foundations

The geographic space where the EFC locates has been reconfigured over the years by mineral exploration. The economic activities developed in the most diverse regions, including the Amazon region, are engendered by social, economic, and environmental factors; thus, it is fundamental to analyze the relationship between these factors since they directly influence the reconfiguration of spaces.

Changes in land use and occupation also reconfigure the spaces; The joint study of these changes with the socio-economic and environmental indicators analysis in a complex region (due, for example, to its high biodiversity and the large number of social actors that operate there) like the Amazon becomes even more challenging when dealing with a scale as specific as that of communities. The absence of data on areas in the scale of detail makes it even harder to develop studies at this level.

Segerstedt and Abrahamsson (2019) highlight that the use of mineral resources is essential to human wellbeing and social life; and that the extraction of these resources is associated with many challenges. The latter is even higher when they involve the health and well being of workers and residents of locations close to mining enterprises. Understanding the change in land use and land cover is fundamental to analyze the influence of activities on nearby communities.

Simultaneously, the dissemination of the idea of sustainable development has increasingly guided academic work, which makes analyses in search of a sustainable path or solution in the most diverse areas of study, including land use (see Vieira et al., 2014 and Amado, 2005).

When talking about territory, we immediately refer to the power relations that develop there. Haesbaert (2014) states that we differentiate territories according to the relationships that individuals, social groups, the State, companies, and other stakeholders build; thus, territorialization varies according to society and culture. Therefore, we can define the EFC as a territory from the moment it is considered the social and power relations around it by the most diverse actors.

The range of studies on land use and occupation is rich and has diversified with geographical technologies development. Eiselt et al. (2001) did a socio-economic data analysis of a European project to model inter-regional migration flows and relate them to land cover and land use in Europe. Carvalho (2014) studied the regional economic impact of deforestation control policies in the Legal Amazon, analyzing land-use dynamics. Ruan et al. (2016) evaluated land use and land cover changes over 12 years in a Canadian province relating socio-economic, demographic, and environmental data. Souza-Filho et al. (2018) presented an interpretation methodology for a quantitative assessment of land use and land cover changes in the Itacaiúnas River basin, southeast Amazon, from 1984 to 2017; more recently, Souza-Filho et al. (2020) conducted a relevant study about the intensity of land use of mineral extraction in the Amazon region, through economic and spatial data.

These studies show the importance of the relationship of land use and occupation analysis with socioeconomic, demographic, and environmental data on the Amazon region, more specifically the EFC territory, which historically presents precarious socioeconomic indicators - except in municipalities that concentrate mines and high infrastructure - together with various environmental pressures in the region (ITV, 2017).

Analysis of demographic data, population growth, migratory flows is also identified in several studies that examine land use and occupation. Bell et al. (2010) reviewed data on migration and land use in Europe. Bonilla-Moheno (2012) evaluated the effect of demographic, environmental, and socioeconomic variables on the land cover change between 2001 and 2010 for Mexican municipalities and biomes using secondary data; Jokinen (2018) analyzed how transnational labor migration was affecting agricultural practices and land use in two-grain producing communities in Bolivia using mixed data.

Some municipalities in the EFC's influence area had already received intense migratory movements since its implementation (ITV, 2017), clarifying its importance since the beginning of this region occupation. These movements have a direct influence on the change of land cover in the railroad's territory. When it is simultaneously observed the evolution of socioeconomic data, for instance, from 1991 to 2000 (Census, IBGE), this becomes clearer.

Bell et al. (2010) explain the complicated connection (which must be deepened by scholars) between migratory movements and land-use changes. The latter responds to the pressures arising from migration that occurs in different ways and places.

Few studies focused on sustainability and land use at the community level, especially for territory as specific as the EFC in the Amazon region. Segerstedt and Abrahamsson (2019)

analyzed social challenges in mining, describing social sustainability from the mining companies and the community's viewpoints, identifying a gap in this literature.

Segerstedt and Abrahamsson (2019) argue that researchers should define social sustainability in these communities by considering the often unique circumstances these communities have in common, such as the need to deal with the changes associated with dams and mining recessions. In this study, the changes occurred in mining activity, the railway structure and its implementation, and its recent duplication (Vale, 2018).

The reality of communities influenced by mining activities is complex, and studies in this area are needed. Cross (2001) argues that people in rural communities or small towns are more vulnerable than those in large cities and urban areas due to the lack of preparation for risk situations.

The 2002 International Mining, Minerals, and Sustainable Development (MMSD) report is a relevant reference for mining companies in their relationship with communities near mining enterprises, doing research and consultation, examines relationships between the world's mineral system and the sustainable development objectives. The project ended in mid-2002 and resulted in a Breaking New Ground report (Starke, 2002).

Two of the chapters of MMSD deal specifically with the Control, Use and Management of Lands and Local Communities and Mines, demonstrating the importance of assessing the influence of land use and land cover on the treatment of issues involving mining companies and communities, always seeking to make mineral production and exploration meet human needs in the most sustainable way possible.

In this study, the concept of land-use change by the Ministry of Science and Technology (MCT, 2010) has been used, which classifies it as the forest conversion in areas for other purposes such as pasture, agriculture, or other forms of land use. According to IBGE (2006), within the debate on sustainable development, it is fundamental to take into account the characterization of the processes of land use, the factors that lead to change, and the expectation of environmental justice due to different interests, civil rights, and conflicts involving natural resources. Thus, the concept of sustainable development encompasses the joint vision of land use, preservation, conservation, and environmental justice (IBGE, 2006).

Vieira et al. (2014) found that the Amazon has historically been the target of actions aimed at its integration and pursuit of development, translated into the construction of large infrastructures and projects, which generally do not contemplate the social and environmental dimensions in a manner equivalent to the economic; Thus, the authors emphasize that the

distribution of land use and coverage reflects the policies historically implemented in the region.

Despite being an undeniable result of mining and other activities development, scholars have linked the changes in land use identified in the studied territory to the historical development and occupation of the Amazon region. Researchers should consider this aspect in a joint analysis of socioeconomic indicators with demographic and environmental data, seeking risk reduction and building resilience in these locations.

Risk reduction and building resilience are undisputed products of effectively establishing social justice and maintaining ecological integrity, both of which are directly related to sustainability according to Freitas et al. (2012), and priority points among the Sustainable Development Goals (SDGs) established by the UN to achieve by 2030 (Agenda 2030).

3. Methodology

This paper studied the living conditions of rural and urban communities of the EFC through the analysis of 17 social and economic indicators. The environmental dimension was considered by examining land use and occupation from the qualitative analysis of satellite images obtained from Google Earth for 2010 and 2017. The study confirmed whether the socioeconomic indicators (which portray the local living conditions) result from land use and occupation patterns.

The methodological procedures carried out are as follows. First, social and economic data were collected; secondly, statistical tests for data significance analysis were applied using the Stata 13.1 software; then the Google Earth satellite images between the 2010-11 and 2017 periods were analyzed visually; finally, the data evolution based on visual image analysis was compared.

This study presents an experiment that compares secondary data from 32 communities from the 2010 census (IBGE) and primary data collected in person using a questionnaire during field research in the biennium 2016-17. Socioeconomic indicators complement the analysis of land-use and land cover changes based on satellite images to verify the relationship between the data collected and the estimates made based on the image analysis.

The fieldwork, done with researchers from the Vale Institute of Technology, surveyed 1,906 households (Table 1) in 2016 and 2017. The samples were defined, in each community,

with 95% confidence and a 3.5% margin of error, which is higher than 5% - often used in many surveys, to ensure high reliability of the research results.

The households researched were randomly selected; to respect the ethical standards of research of the Vale Institute of Technology (Vale, 2013), the anonymity of respondentes was ensured; Adults 18 years of age or older and enough knowledge to answer all the questions in the questionnaire were interviewed; the data were prepared in an Excel spreadsheet and analyzed statistically in the Stata software (StataCorp, 2013).

Table 1 – Field data stratification

Sample	Pará	Maranhão	Total
Number of municipalities	3	12	15
Number of households surveyed	722	1,184	1,906
Total number of communities surveyed	13	36	49
Number of excluded communities	3	14	17
Number of communities considered	10	22	32
Number of households considered	687	1,011	1,698

The 49 communities were reduced to 32 due to discrepancies between the 2010 and 2016/2017 data. Several numbers of households or populations were smaller or much higher than those identified during sample definition for the fieldwork; This occurred because of data limitation at the census tract level, where polygons previously defined many times covered areas higher than the communities. These situations were confirmed from the images analysis and visual count of the number of homes in the communities' images, identifying the inconsistency that justified their exclusion from this analysis.

Limitations in the data collection of the census tracts were verified: first, the variation of the polygons of these tracts in each census, so the most recent census (2010) was chosen in detriment of the others, which allowed a real inter-census comparison at the tracts level; second, the availability of the data of the census tracts, since the variables in this scale are not equivalent to all those collected by IBGE at the municipal level.

In parallel, a visual analysis to compare the land-use and occupation changes and those of indicators were made; This visual analysis corresponded to the environmental dimension, and it was done through the detailed observation of the temporal sequence of images in the 32 communities from the location of their geographic coordinates, taking into account the community surroundings, the number, and placement of homes, the existence of vegetation,

253 infrastructure related to the railroad, the water bodies, and roads. The amount of data varied
254 between the 2010 census and the fieldwork; in this, the questionnaire applied to analyze the
255 communities living conditions concerning the EFC influence was designed; Thus, as mentioned,
256 the primary dataset is large because it covers specific interests; The appendix presents the
257 variables collected, their definitions, and treatment according to the 2010 census and the
258 questionnaire applied during the field research at the EFC.

259 In all variables, the Kolmogorov Smirnov normality test was performed to identify
260 whether the data followed a normal distribution. If positive, the parametric Student's t-test
261 was applied to each variable; otherwise, the nonparametric Mann-Whitney and Kruskal-Wallis
262 tests (Kruskal, 1952; Birnbaum, 1956) were used; The variables that presented different
263 averages between urban and rural communities in each year were identified and the
264 difference in their variation between the years was analyzed, at the 5% significance level.

265 **4. Results**

266 *4.1. Socioeconomic and Demographic Analysis*

267 Socioeconomic data of the 32 communities studied show that they had different
268 conditions. Tropical I, Tropical II, and Nova Ipiranga communities and the Agroplanalto
269 Settlement did not exist yet in 2010; therefore, they were considered only in the
270 environmental dimension analysis.

271 Demographic analysis of communities between 2010 and 2017 shows an overall
272 population increase. Nova Vitória, located in Parauapebas, Pará; Periz de Cima, located in
273 Bacabeira, Maranhão; and Km 7, in Marabá municipality, Pará, had the highest growth rates,
274 25%, 22%, and 20%, respectively. Vila Pindaré, Cariongo 3, Nova Vida, and São Benedito (the
275 first with a rate of -2% and the last three with -1% each) were the only ones without
276 population growth, presenting a small reduction (Figure 2); These rates were inconsistent with
277 that of approximately 1%, verified in each of the reference regions of Pará, Maranhão, and
278 Brazil.

279 Figure 2 here

280 In 2010 and 2017, the communities with the largest populations were urban; all with
281 falling population growth rates were rural, although two of the three with the highest rates
282 were also of this type. In 2010, based on the Kolmogorov-Smirnov test, we identified that the
283 13 demographic and socioeconomic variables did not present a normal distribution (Table 2).
284 From the Mann-Whitney and Kruskal-Wallis nonparametric tests, we verified the differences in
285 the means of these variables between urban and rural communities in 2010 (Table 2).

Table 2. Results of statistical testing of differences in the means between urban and rural communities in 2010

Variable	Difference of averages	Mann-Whitney Test
Households	820**	z= -3.514; Prob > |z|= 0.0004
Residents	3,136**	z= -3.302; Prob > |z|= 0.0010
Children and youth	-6**	z= 3.471; Prob > |z|= 0.0005
Total income	US$ 525,427.00**	z= -3,810; Prob > |z|= 0.0001
Income per capita	US$ 52**	z= -3.090; Prob > |z|= 0.0020
Poverty	-11**	z= 3.366; Prob > |z|= 0.0008
Literacy	7**	z= -3.852; Prob > |z|= 0.0001
Refrigerator	15**	z= -4.361; Prob > |z|= 0.0000
Television	8**	z= -3.641; Prob > |z|= 0.0003
Radio	8**	z= -4.233; Prob > |z|= 0.0000
Cell phone	31**	z= -4.361; Prob > |z|= 0.0000
Occupied population	4**	z= -2.860; Prob > |z|= 0.0042
Households with sewage	32**	z= -2.930; Prob > |z|= 0.0034

Note: Kolmogorov-Smirnov's normality test was performed on all variables and, depending on the conclusion of this test; other tests were done: Student's t, when the data followed a normal distribution, or Mann-Whitney, whose result was confirmed by the Kruskal-Wallis test (result omitted here) when the null hypothesis of data normality was rejected; **= significant at 5%.

Difference of means=variable average in urban communities *minus* its average in rural communities. This note is also valid for the Tables 3 and 4.

Statistically significant differences at 5% in the 13 variables in 2010 (Table 2) were confirmed; Concerning demographics, the number of households and residents in urban communities was higher than in rural ones, with the opposite occurring about children and youth.

Regarding socioeconomic variables, total income and per capita income in urban communities were higher than in rural ones, occurring the opposite concerning the poverty variable, as expected. Vila Ildemar (US$2.5 million) in Açailândia municipality, Maranhão; Km 7 (approximately US$1 million) in Marabá, Pará; and Pedrinhas (roughly US$0.8 million) in São

Luís, Maranhão, had the highest total household income and were the most populous communities.

In contrast, the communities of Maranhão Atraca, in Tufilândia, Cariongo 3, in Miranda do Norte, and São Benedito, in Igarapé do Meio, presented the lowest total incomes, US$13,297, US$41,046, and US$36,349, respectively, being the last two communities among the three with the lowest population.

Regarding per capita household income, the communities Km 7 in Marabá, Pará, and Fumacê, in São Luís, presented the highest levels, with US$240 and US$205, respectively. On the other hand, Atraca (US$54), Monge Belo (US$57), and Nova Vida (US$59), in Bom Jesus das Selvas, all in Maranhão state, had the lowest incomes. São Benedito, Atraca, and Nova Vida - all in Maranhão - had 32%, 30%, and 27% of their households in poverty, respectively, with a household per capita income until US$36 or one-eighth of 2010 minimum wage (US$290).

The number of literate people, an economically active population occupied, households with sewage, number of refrigerators, televisions, radios, and cell phones was higher in urban communities. Vila Conceição (25%), Km 7 (25%) and Fumacê (24%) presented the highest amount of literate people responsible for the household, and Cariongo 3 (4%), APA do Gelado (12%), Nova Vitória (12%), and São Benedito (12%) were the worst communities in this variable.

In 2017, only eight variables had statistically significant results (Table 3). Of these, only two followed a normal distribution: children and youth, and households with sewage; for the latter variable, the Student's t-test confirmed a higher number in rural communities than in urban ones, and the opposite in the former.

In the remaining six variables, we rejected the normality hypothesis. The Mann-Whitney and Kruskal-Wallis non-parametric tests showed that concerning durable goods, the number of cell phones in urban communities was higher than in rural ones, occurring the opposite for the motorcycles. Households, residents, total income, and per capita income in urban communities were again higher.

Vila Ildemar, Açailândia, in Maranhão, remained with the highest total income among the 32 communities (US$233,673), followed by Palmares II (US$80,347), in Parauapebas, and Km 7 (US$70,674), in Marabá, both in Pará. The location of these communities is in economically relevant municipalities of the railroad. Açailândia municipality has the fourth-largest GDP in Maranhão state; Parauapebas and Marabá have the second and third largest

GDP in Pará (IBGE, 2017) and are relevant municipalities in the State's Southeast region, where companies develop industrial mining.

Table 3. Results of statistical tests of the differences in the means between urban and rural communities in 2017

Variable	Difference of averages	Mann-Whitney Test
Households	61**	z= -2.812; Prob>|z|= 0.0049
Residents	242**	z= -2.710 Prob > |z|= 0.0067
Total income	US$ 28,889.00**	z= -3.048; Prob > |z|= 0.0023
Income per capita	US$ 37.00**	z= -3.133; Prob > |z|= 0.0017
Cell phone	13**	z= -2.312; Prob > |z|= 0.0208
Motorcycle	-26**	z= 3.262; Prob > |z|= 0.0011

Note: In 2017, among the variables that presented significant results at 5%, only children and young and households with sewage variables had normal distribution; the Student's t-test were Pr(T > t)=0.0228; t=2.09 and Pr(T < t)=0.0318; t=-1.96, respectively.

Cariongo 3 (US$1,324) and São Benedito (US$1,391), again, presented the lowest total incomes and were among the five communities with the lowest population in 2017. Bairro Araguaia (US$171), in Marabá, and Vila Conceição (US$157) and Gapará (US$143), both in São Luís, had the highest per capita household income. Monge Belo (US$30), in Anajatuba, São Benedito (US$40), and Cariongo 3 (R$40) - again, all in Maranhão state - presented the worst household income per capita.

Regarding the percentage variation between 2010 and 2017, nine variables studied had statistically significant results (Table 4); only the people born in the Federation Unit (FU) variable presented normal distribution with the Student's t-test confirming the highest percentage variation in urban communities in the analyzed period.

Table 4: Results of the tests for the differences in the means of variations from 2010 to 2017 between urban and rural communities

Variable	Difference in the means of variations	Mann-Whitney Test
Total income	US$ -496,538.00**	z = 3,683 Prob > |z| = 0,0002
Poverty	-6,747**	z = -2,413 Prob > |z| = 0,0158
Literate people	-222**	z = 3,937 Prob > |z| = 0,0001
Refrigerator	-19**	z = 3,387 Prob > |z| = 0,0007
Television	3**	z = 2,604 Prob > |z| = 0,0092
Cell phone	-49**	z = 3,387 Prob > |z| = 0,0007
Motorcycle	-116**	z = 3,175 Prob > |z| = 0,0015
Hosehoulds with sewage	-119,022**	z = 2,252 Prob > |z| = 0,0243

Note: Among the variables that presented significant results at 5%, only the people born in the Federation Unit variable had a normal distribution. Student's t-test result was Pr(T < t)= 0.0279; t = -1.995.

During the 2010-17 period, 15 communities reduced the number of household heads born in the Federation Unit where they locate. Nova Jerusalém and APA do Gelado, both in Pará, in Canaã dos Carajás and Parauapebas municipalities that concentrated the key mines of the territory presented the highest reduction in this variable, which indicates an increase in migration flows towards these locations.

The communities of Pará, especially Parauapebas, Canaã dos Carajás and Marabá, were the ones that had most residents from other states; These municipalities are a reference in the socioeconomic context of the EFC territory and, the economic factors were fundamental for movements to these communities (Santos et al., 2019), which only three of them were urban (out of nine located in these three municipalities).

For the other eight variables, we conducted non-parametric tests. As a result of the percentage variations in the data of the variables cited between 2010 and 2017, the variation in total income, poverty, literacy, and households with sewage was higher in rural communities than in urban ones. Concerning the durable goods, the percentage variation in the number of refrigerators, cell phones, and motorcycles in rural communities was higher, occurring the opposite for the television variable.

APA do Gelado, in Parauapebas, Pará, and Nova Vida, in Bom Jesus das Selvas, Maranhão, showed a 100% fall in households in poverty. Nova Vida stood out as one of the three communities with the highest poverty in 2010, despite showing a significant improvement in almost a decade. From the analysis of the data, it was also clear the increase in literacy. Cariongo 3 community increased more than 15 times its literacy, followed by São Benedito and Nova Vitória, which increased this indicator more than eight times.

Only the variables total income, cell phones, and households with sewage were significant at the levels and changes analyzed. As far as a household with sewage is concerned, Primeiro Cocal, Piquiá de Baixo, Atraca, Cariongo 3, Vila Jacu, and Vila Conceição, without access to sewage in the public network in 2010, started to have this service in 2017. Vila Conceição stood out with a 100% increase in households with public network sewage in 2017. Overall, all communities improved in this indicator.

4.2. Environmental Dimension

Our findings differ among the communities. The Agroplanalto Settlement, Tropical I, Tropical II and Nova Ipiranga, and Nova Vitória communities - the first in Açailândia, Maranhão, and the last two in Parauapebas, Pará - had the most relevant change in land use and coverage from 2010 to 2017. The birth of the first two was during this period, generating a significant alteration in these areas. The images analyzed below are illustrative examples due to the limited space, and all for the 32 communities are available upon request.

In the analysis of the 2011 image of the Tropical I, II, and Jardim Ipiranga communities (Figure 3a), one could only see a large area of pasture/vegetation, with some points in the surrounding areas focused on industrial activities. In 2017, the households occupied the entire pasture area (Figure 3b), and a community expansion of 100% and the Southeast Pará railway branch on its east can be identified.

Figures 3a and 3b here

Nova Vitória, Tropical I, II, and Nova Ipiranga locate between the Southeast Pará railroad branch and the EFC; The expansion of the former and the creation of the latter are related to the railway extension, which occurred in parallel, connecting the mine in Canaã dos Carajás to the EFC, in Parauapebas. The expansion and significant change in land cover in the areas of these communities, including the suppression of vegetation and increase in the human occupation, are consistent with the changes in their socioeconomic and demographic data; Nova Vitória, for example, had the highest population growth rate in the period studied, which we proof from the analysis of the 2010 and 2017 images (Figures 4a and 4b).

Figures 4a and 4b here

Besides Nova Vitória, Periz de Cima and Km 7 presented the highest growth rates. Although Nova Vitória and Km 7 (Figures 5a and 5b) had images consistent with such growth, Periz de Cima does not appear to have presented such significant change in the number of homes, despite having changes in the ground cover, for example, with the construction of a viaduct over the railroad in the northwest portion of the community's location (Figures 6a and 6b). Among these, only Km 7 is directly crossed by the railroad, although Periz de Cima locates very close to it.

Figures 5a and 5b here

Figures 6a and 6b here

Other communities, such as Nova Vida and São Benedito, showed practically no demographic change, which we confirm by the image analysis. Although the second had some changes in the land cover with reduction of vegetation cover mainly in the northern and southern portions of the community, there was no significant change in their number of households (Figures 7a and 7b); The socioeconomic data show a small reduction in the growth of these areas, and in Vila Pindaré and Cariongo 3, all rural. Among these four communities, the railroad crosses all but São Benedito.

Figures 7a and 7b here

Vila Maranhão, Vila Jacu, and Sitinho are three urban communities very close to each other in São Luís, Maranhão. The area where they locate had a significant change in land cover between 2010 and 2017, especially the one closest to Vila Jacu, located next to the railroad, where viaducts were built over it by the railway concessionaire (Figures 8a and 8b). Except for Vila Jacu, a rural community, the others are urban ones crossed or located next to the railroad.

Figures 8a and 8b here

The results show that the majority of communities presented changes consistent with socioeconomic indicators and satellite image changes. Overall, the communities on the Maranhão side of the railroad almost always appear among those with the worst socioeconomic indicators, e.g., the Cariongo 3, São Benedito, and Atraca located in Miranda do Norte, Igarapé do Meio, and Tufilândia municipalities, respectively, demonstrating that they face more difficulties in achieving sustainability. This picture clarifies the need to implement actions to reduce risks, increasing the community resilience, always seeking to achieve more sustainable conditions (Chaskin, 2008; Magis, 2010; Berkes and Ross, 2013).

Many studies on the Amazon call attention to its eastern portion, where there is a relationship between mining and the municipalities' conditions and population (Moran et al., 1996; Holmes et al., 2002; Souza-Filho et al., 2019). This study confirms the importance of carrying out research involving municipalities and communities influenced by mining; it highlights the need for actions to achieve more sustainable conditions, considering that analyses showed that a lack of sustainability still prevails in most of the communities studied.

5. Discussion

Despite growing, there are still few studies involving the EFC territory. Previous studies have analyzed this territory as a whole, without focusing on communities, generally concerned with biological, physical, and environmental analyses (e.g., Falesi et al., 1986; Coelho, 1997; Corteletti; 2014; Santos, 2016; Damasceno et al., 2017); Santos et al. (2018) worked on a community scale, but they focus on the analysis of the networks of institutions functioning in them.

This study fills a relevant gap in the EFC literature; it focuses on the detailed scale of communities and jointly analyzes the evolution of their socioeconomic status with satellite images to understand land use and occupation changes. Besides, the analysis covers almost a decade, ensuring an inter-census analysis, since it also used fieldwork data that overcome the absence of data between decadal censuses.

The three hypotheses of this research were accepted based on the socioeconomic data and the satellite image analysis. The location of communities along the railroad is related to forms of land-use and occupation in the territory, and such location directly influences the living conditions of the local population since the communities located very close to the railroad, or crossed by it, are generally those that had the most significant changes in land coverage and use and the highest variation in socioeconomic indicators.

In 2010, of the 20 variables tested, 13 showed statistically significant results, confirming differences between urban and rural communities; Of these, in 11 the urban communities had the highest averages, occurring the opposite in only two variables - number of children and youth, and households in poverty. In 2017, of the 20 variables tested, only eight were significant, confirming higher averages in urban communities in six variables, happening the opposite in only two variables - number of children and youth and households with motorcycles. The communities were statistically identical in 12 variables.

In the analysis of variables variation from 2010 to 2017, of the 20 variables analyzed, only nine were statistically significant, and higher percentage variations among rural communities were confirmed in seven variables, occurring the opposite in only two variables - people born in the Federation Unit and households with a television.

The social and environmental community conditions are not related to its location concerning the railroad; in other words, the latter is independent of urban or rural. Overall, the study has shown that urban communities present better conditions than rural ones; we understand these disparities when previous studies on the Amazon region are analyzed, which demonstrate that the living conditions of the population are also the effect of the historical formation process of municipalities in the Amazon region, thus confirming our third research hypothesis.

6. Conclusion

This study analyzed the use and coverage of land and the household conditions of 32 communities in the EFC territory. Socioeconomic and demographic data and satellite images from Google Earth from 2010-11 to 2017, covering almost a decade, were used.

Previous studies on the EFC territory have limitations. Some focus on only one dimension of sustainability; others are cross-sectional or focus on specific areas. This study is innovative because it presents a holistic analysis at a detailed scale, considering the three main sustainability dimensions using secondary and primary data.

The main conclusions are as follows. Overall, the communities on the Maranhão railroad side are in a less sustainable situation, especially the Atraca, Cariongo 3, and São Benedito, which had some of the worst performances in the analyzed indicators; The communities of Parauapebas, Marabá, Canaã dos Carajás, Açailândia, and São Luís are in better condition.

The three hypotheses of this study were accepted; The data directly describe the community residents living conditions. In general, the urban communities presented better conditions. The railroad is directly related to land use and occupation; the latter two features are associated with communities' location within the territory, influencing the local population's living conditions.

The satellite images and socioeconomic data analysis in defined periods can subsidize actions to reduce risk situations and increase resilience and sustainability through public policies or private initiatives; this is fundamental in rural communities as they had the worst indicators. Future studies can consider a larger number of communities and indicators, cover a higher period, and comparing land cover and land use changes in this territory, ensuring constant actions according to the community conditions evolution.

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Compliance with Ethical Standarts

Conflicts of interest/Competing interests The authors declare that they have no conflict os interest.

Ethical Aproval The interviewees' anonymity was assured, given the ethical standarts for research at the Instituto Tecnológico Vale (ITV).

Informed Consent The interviewees verbally agreed to participate and a written agreement was not required.

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