Universidade do Contestado | www.unc.br/periodicos ISSNe: 2237-9029
DRd | Desenvolvimento Regional em debate
Revista eletrônica do Programa de Mestrado em Desenvolvimento Regional da Universidade do Contestado

ANÁLISE SOCIOECONÔMICA DO MAIOR DESASTRE AMBIENTAL DO BRASIL

SOCIOECONOMIC ANALYSIS OF THE BIGGEST ENVIRONMENTAL DISASTER IN BRAZIL

ANÁLISIS SOCIOECONÓMICO DE LA MAYOR CATÁSTROFE MEDIOAMBIENTAL DE BRASIL

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RESUMO

O colapso de uma barragem contendo rejeitos de mineração em 2015 é reconhecido como o maior desastre ambiental da história do Brasil. Milhões de metros cúbicos de lodo foram despejados na natureza. O ecossistema aquífero de uma região de 35 municípios foi afetado, totalizando 1,2 milhões de habitantes privados de água e suscetíveis à contaminação mineral. Os impactos foram muito além da dimensão ambiental. Neste sentido, foram analisadas as consequências socioeconômicas deste desastre sobre as condições de vida da população do município de Mariana (MG/Brasil), onde se encontrava a barragem. Com base em dados secundários oficiais e dados primários derivados de uma amostra composta de 256 entrevistas, foi utilizado o método *Alkire-Foster*, para avaliar as condições multidimensionais de pobreza nas quais os habitantes daquela região se encontram. Entre os resultados, evidencia-se que o número de empregos, o salário médio e a receita tributária em Mariana diminuíram no período após o colapso da barragem, fazendo com que a proporção de pessoas pobres e o nível de privação dos habitantes aumentasse. Complementarmente, observa-se um crescimento de cerca de 280% na incidência da pobreza *ex post facto*. O mapeamento dos impactos multidimensionais e o planejamento estratégico das ações para enfrentar as vulnerabilidades permanecem entre as prioridades imediatas para a região.

Palavras-chave: Pobreza multidimensional. Vulnerabilidades socioeconômicas. Método *Alkire-Foster*.

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ABSTRACT

The collapse of a dam containing mining tailings in 2015 is recognized as the biggest environmental disaster in Brazil's history. Millions of cubic meters of sludge were dumped into nature. The aquifer ecosystem of a region of 35 municipalities was affected, totaling 1.2 million inhabitants deprived of water and susceptible to mineral contamination. The impacts went far beyond the environmental dimension. In this sense, were analyzed the socioeconomic consequences of this disaster on the living conditions of the population in the municipality of Mariana (MG/Brazil), where the dam was located. Based on official secondary data and primary data derived from a sample composed of 256 interviews, was used the *Alkire-Foster* method, to assess the multidimensional conditions of poverty in which the inhabitants of that region find themselves. The results show that the number of jobs, the average wage, and tax revenue in Mariana decreased in the period after the dam collapse, causing the proportion of poor people and the level of deprivation of the inhabitants to increase. In addition, there has been a 280% increase in the incidence of poverty *ex post facto*. in the incidence of poverty *ex post facto*. The mapping of multidimensional impacts and strategic planning of actions to address vulnerabilities remain among the immediate priorities for the region.

Keywords: Multidimensional Poverty. Socioeconomic vulnerabilities. *Alkire-Foster* Method.

RESUMEN

El colapso de una represa que contenía residuos mineros en 2015 está reconocido como el mayor desastre medioambiental de la historia de Brasil. Millones de metros cúbicos de lodo se vertieron en la naturaleza. Se vio afectado el ecosistema acuífero de una región de 35 municipios, con un total de 1,2 millones de habitantes privados de agua y susceptibles a la contaminación mineral. Los impactos fueron mucho más allá de la dimensión medioambiental. En este sentido, fueron analizadas las consecuencias socioeconómicas de este desastre en las condiciones de vida de la población del municipio de Mariana (MG/Brasil), donde se encontraba la represa. A partir de datos secundarios oficiales y de datos primarios derivados de una muestra compuesta por 256 entrevistas, fue utilizado el método *Alkire-Foster*, para evaluar las condiciones multidimensionales de pobreza en que se encuentran los habitantes de esa región. Los resultados muestran que el número de empleos, el salario medio y los ingresos fiscales en Mariana disminuyeron en el periodo posterior al colapso de la represa, lo que provocó un aumento de la proporción de pobres y del nivel de privación de los habitantes. Además, se ha producido un aumento alrededor del 280% en la incidencia de la pobreza *ex post facto*. La cartografía de los impactos multidimensionales y la planificación estratégica de acciones para hacer frente a las vulnerabilidades siguen figurando entre las prioridades inmediatas de la región.

Palavras clave: Pobreza multidimensional. Vulnerabilidades socioeconómicas. Método *Alkire-Foster*.

Como citar este artigo: SANTOS, Vinícius Fortes da Silva; TROIAN, Alexandre; OLIVEIRA, Sibele Vasconcelos de. Análise socioeconômica do maior desastre ambiental do Brasil. **DRd - Desenvolvimento Regional em debate**, v. 14, p. 494-514, 21 ago. 2024. Doi: https://doi.org/10.24302/drd.v14.4727.

Artigo recebido em: 28/02/2023
Artigo aprovado em: 19/07/2024
Artigo publicado em: 21/08/2024

1 INTRODUCTION

Mariana was the first city founded in Minas Gerais/Brazil and is renowned for the historical development of that state. On November 5, 2015 the municipality was in the national and international media spotlight, not for its beauty and historical wealth, but for having been the scene of the biggest environmental disaster in Brazil. At the time, the Fundão dam, which belonged to Samarco Mineração S.A. and served as a deposit for mining waste, collapsed.

The accident in the Bento Rodrigues district spilled 55 million cubic meters of mud and ore tailings. The sludge traveled 663 kilometers until reaching the Atlantic Ocean, resulting in11 tons of dead fish being observed in the region. The tragedy killed 19 people and left at least 1,200 people homeless (PORTO, 2016). The event's immediate implications included the devastation of residences, the contamination of rivers and, consequently, the damage to the aquatic environment (BARROS; PAMBOUKIAN, 2017).

Thus, the Mariana disaster has raised the interest of researchers from the most diverse areas of scientific knowledge in exploring the multiple dimensions and impacts of the phenomenon on human and animal life. It is important to think of all the fauna and flora affected by the mud, the consequences of the pollution on the Doce River basin, and many other plausible study objects to be investigated.

From a socioeconomic perspective, it is worth reflecting on the disaster's impact on the social reproduction dynamics of the affected municipalities, both in terms of the capacity for economic growth and the conditions for the recovery of social welfare. Thus, research that focuses on the conditions of access to health, work and education, well-being, and human development in the region is pertinent.

It is worth pointing out that, people made their livelihood from the rivers affected by the dam collapse in Mariana, either by fishing or by exploiting the water resources for crop irrigation. Furthermore, the people of the region used the water for their own consumption, so the impact went far beyond the environmental dimension, also incorporating reflexes on social and economic variables.

César and Carneiro (2017) emphasize the mining activity's importance to the state of Minas Gerais. The activity is present in more than 400 municipalities, and occupies an important position in the state's exportation agenda. Therefore, the Mariana disaster is also expected to have repercussions on the region's capacity to generate employment and income.

Through the implementation of the *Alkire-Foster* (*A-F*) method, this study aims to analyze the multidimensional poverty index for Mariana (MG/Brazil), before and after Fundão Dam collapse. Thus, primary and secondary data from the municipality of Mariana/MG/BR were used to describe the main socio-economic transformations resulting from the dam collapse in that region. The paper is structured in five sections, including this introduction. The next section deals with the transformations incorporated in the concept of poverty and the emergence

of a multidimensional perspective in its conception. The third section presents the methodological procedures employed for estimating the multidimensional poverty index. The fourth section analyzes the study's main results. Finally, the conclusions of the study and the bibliographical references used are presented.

2 THEORETICAL REFERENCE: EVOLUTION OF APPROACHES THAT ANALYZE POVERTY

Poverty is among the phenomena in the Social Sciences that are controversial regarding their definition. Several researchers agree it is difficult to distinguish a poor person from a non-poor person, a fact that leaves room for much debate. Therefore, we discuss how the concept has been transformed over time to incorporate multiple dimensions into its scope.

It is worth noting that the discussion on poverty intensifies in England during the industrial revolution, with the observation of the growth of social problems, the population's low quality of life, and hunger. During this period, people began to discuss the living conditions of the lower social classes, who earned insufficient income to cover all basic expenses.

Thus, we can see that the debate on poverty emerged with the discussion regarding the income problem of the most vulnerable population. The concern was to generate means that would make it possible to provide the most basic needs for the survival of the least favored population. Especially in England, there was the emergence of projects and benefits aimed at supporting the most fragile people, such as: the Compensation Act (1897), the compulsory health insurance (1912), the unemployment insurance (1920), among others (BEVERIDGE, 1942).

Although this is a good starting point for the poverty analysis, just meeting the subsistence conditions does not guarantee that a person will or will not be poor. Analyzing basic physical needs is to superficially and incompletely address the poverty issue since the phenomenon transcends basic physical needs. In fact, there is a vast literature criticizing the idea of studying poverty based only on the subsistence and income level notion.

Among the main arguments criticizing the subsistence approach to poverty is the claim that people need more than just a satisfactory income to meet their basic physical needs. In order to promote life quality, people must contemplate the other dimensions of the complex social system in which they live. Sen (2000) points out that the utility of wealth is linked to the possibility of what it offers. However, this relationship between wealth and freedom is not exclusive since there are other influences in our lives that wealth cannot supply, such as freedom of speech or opportunities.

Thus, Chambers (2006) points out that another school of thought on poverty emerged in the 1970s, strongly supported by the International Labor Organization (ILO). This school of thought linked poverty to access to elements that meet the "basic needs" of individuals, classified from two perspectives: basic consumption needs (such as adequate food, shelter, clothing, furniture, and equipment) and basic needs for society or the collective (such as drinking water, sanitation, public transportation, public facilities, health services, education, and culture). In addition to basic material needs, Chambers' perspective also analyzes the more

complex needs for economic and social development, both at the individual and community level.

It is worth mentioning that, since the 1980s, poverty studies have become more dynamic, more comprehensive, and with more rigorous methods and analysis. Scholars sought a more scientific formulation on the poverty study, and comparisons and links of their studies to other research on poverty around the world. Crespo and Gurovitz (2002) argue that, since 1980, research on poverty has taken a multidimensional analysis path, where not only people's basic needs and subsistence needs are analyzed, but also people's and society's rights and freedoms.

In the meantime, we point out that the multifaceted approach opposes the idea of delimiting the research agenda on poverty to the definition of a poverty line (by assessing the income level of individuals, for example). From this perspective, income is not the key (or exclusive) indicator to analyze the poverty level, and we are looking for parameters that demonstrate effective results on life quality. Still, the multifaceted approach aims at generating an analysis of society as a whole and not delimiting a subpopulation (ROCHA, 2003).

Under the income poverty approach, Romão (1982) mentions that even if there were a coherent theoretical system regarding the concept, the struggle over the distinction between poor and non-poor would still persist since it is not possible to determine precisely, for example, what level of income would make a person non-poor. In fact, the question is: under what criteria is a person considered poor in income terms? According to the World Bank, a person is below the poverty line when living on less than US$2.15 a day. However, the status of a person who has an income of approximately US$2.00 is debated. This International Poverty Line is defined on the basis of the 2017 Purchasing Power Parity published by the World Bank (DIAZ-BONILLA, 2023). In this case, would the person live in better conditions than a person below the World Bank's estimated value?

Romão (1982) states that scholars have not yet reached consensus on an "optimal" relative measure that would better reflect the relative position of the poor. Even if there is a theoretical system that can coherently define the poverty concept, other specificities hinder the concept's standardization, such as cultural differences, geolocation, and other aspects.

Rocha (2003, p.10) points out that the poverty concept must take different forms when applied in different countries. The author argues that countries have different levels of socioeconomic development and different cultural traditions, which gives the sociocultural reality many specificities. Therefore, when it comes to poverty at the international level, the most essential needs must be considered.

Thus, we can see that poverty analyzed from a relative angle tends toward a macroeconomic analysis, and is directly related to inequality in income distribution. In this case, individuals who are in the bottom tier of income distribution are considered poor compared to people who are in better social positions. On the other hand, the absolute approach standardizes the minimum necessary for life quality. This limit or line considers both nutritional and housing aspects, among other basic needs for survival.

Since the poverty study required a broader vision, a new vision emerged in the mid-1980s focusing on a multidimensional approach to poverty. It expands the analysis horizon and has gained ground mainly due to Amartya Sen's contributions to the discussions on human

development, deprivations, and social vulnerabilities. Multidimensional poverty seeks to see poverty not only through the lens of income and basic needs, but by analyzing other dimensions, such as the level of education, safety, health. In other words, all the aspects that are fundamental for a person to have a quality and satisfactory life. Crespo and Gurovitz (2002) point out that the poverty concept can take many forms as it is approached in different ways, such as: "value judgment" idea, which denotes both a subjective and abstract analysis on the individual's satisfaction degree. In particular, regardless of the relative or absolute focus, it is possible to analyze the phenomenon from an economic, cultural, and social point of view.

Filho and Clementino (2020) used three macro dimensions to analyze socioeconomic inequality on a regional scale. These are: housing infrastructure and urbanization; work; and poverty. With regard to poverty, the main indicators used were income and literacy. The results show that, although there is an effort to consider different dimensions in the study, multidimensional poverty is directly related to the lack of economic dynamism. Still on the subject of territorial inequalities, Sousa and Santos (2016), when analyzing multidimensional poverty in the Legal Amazon, used a Family Development Index, which considers six dimensions and 48 indicators in the calculation. The dimensions are: a) absence of vulnerability; b) access to knowledge; c) access to work; d) availability of resources; e) child development; and f) housing conditions. The index results from the arithmetic mean of the indicators of the six dimensions that make it up, with indices below 0.30 being considered very low levels of development. The results indicate that in more than 80% of the municipalities in the Legal Amazon there were improvements in development levels from 2000 to 2010, however, in many municipalities families continue to suffer serious hardships (multidimensional poverty).

Albeit with limits, multidimensional approaches offer the possibility of expanding the scope of poverty analysis and thus contribute to advances in understanding and explaining the phenomenon of poverty, not just as a problem resulting from a lack of income (FAHEL *et al*., 2016). In a more macro analysis, it is possible to find countless people all over the world who suffer from some kind of deprivation associated with poverty. We can mention: collective hunger (in a world that annually discards about 1.3 billion tons of food every year, according to FAO, 2017), which deprives people of the basic freedom to survive; the reality of people who have no access to health services, basic sanitation, or even lack of access to water, and are exposed to premature deaths all the time; the deprivation of access to services such as education, employment, or economic and social security.

Hoorn and Mabsout (2010) argue that the concepts of "capability" and "happiness" convey the life quality idea, although the difference between capability and happiness may lie in the life quality context. According to the authors, the life quality concept depends on two distinct factors: a good life and real life outcomes, and the combination of these two factors can generate life quality. Also, Hoorn and Mabsout (2010) argue that Sen's capability refers to the idea of "power," that is, the idea of possibilities, where people have the ability to improve their lives. In contrast, for Nussbaum (2003), capacity conveys the idea of living a truly human life.

Deprivations are not unique to underdeveloped countries, in many countries the longevity of some groups of people equals or is even lower than that of many third world countries (SEN, 2000). When analyzing poverty with a multidimensional approach, Sen (2000) bases the analysis on the principle of social justice and well-being. Thus, for the author, poverty is no longer something related solely and exclusively to the income or wealth level, but rather

to the choices that are available to people and the lifestyle they have available to choose to live. In other words, the freedom of choice that is available.

For Sen (2000), freedom is something fundamental for the expansion of people's "capabilities" and there are two reasons that lead him to believe this: i) first, when a society has the freedom to do what is really important, it gives people the opportunity to live happily and to generate important results; ii) second, freedom is not only a basis for evaluating the success or failure of a society, but also allows individual initiatives to generate growth and development for the whole society. Therefore, to be free is to have the ability to improve the potential of people to take care of themselves and influence the whole society around them.

Furthermore, Amartya Sen highlights five types of instrumental freedoms that are worth mentioning: i) Political Freedom; ii) Economic Facilities; iii) Social Opportunities; iv) Guaranteed Transparency; and v) Protective Security. The relationships between the instrumental freedoms are essential for a more complete understanding of their role, since freedom is not only the main goal of development, but also the main means of relating these links (SEN, 2000).

Political freedom refers to the opportunities people have to choose who will be the governing representative, and the right to oversee the representative's decision-making and criticize him/her when his/her actions go against the will of the people he/she represents. Political freedom is associated with the idea of an uncensored press, where it is free to expose any public issue with the intention of keeping the population informed. Still, political freedom is associated with the right to democracy, where the population has total freedom to express itself and maintain a dialogue with the representatives making up the government (SEN, 2000).

Furthermore, economic opportunities refer to the opportunities individuals have to enjoy economic means, such as consuming, investing, among other activities. The population's income level is related to the economic development level of the region in which they live. Therefore, a population that lives in a place where it has a high development process, the tendency is that its economic incomes are higher. As a result, these people have greater economic opportunity than people who live in a place with a low economic development level (SEN, 2000).

Social opportunities are related to the availability of essential services (such as education, health, sanitation, among others), which will bring a better life quality to individuals. These rights not only bring benefits to private life, but also contribute to improving society's life as a whole, and make it possible to participate more effectively in economic and political life. For example, in a society with a higher education level, participation in politics tends to become much more effective, because individuals have the knowledge and base their decisions on facts (SEN, 2000).

For Sen (2000), the guarantee of transparency refers to the sincerity level that a person can expect. In other words, the freedom to deal with other people without worrying that something is being omitted while exchanging information. The concept is close to people's definition of honesty. When this freedom is violated, countless people can be negatively affected. This guarantee has an important fundamental role, especially when discussing politics, because this guarantee has an instrumental role, such as inhibiting corruption, financial irresponsibility, and illicit transactions.

Finally, protective security consists in providing social security. It is not only related to the physical safety, robbery, theft, and other crimes, but also includes preventing a population affected by some mishap from being reduced to misery, hunger, and even death. The security sphere guarantees fixed benefits, such as benefits to the unemployed, aid to the indigent and other forms of assistance (SEN, 2000). These instrumental freedoms, combined with individual freedom, have the power to directly influence, by increasing or limiting, people's capabilities. As an example, a population that does not have great economic opportunities will most likely have low political freedom, since it will be more concerned with generating the resources necessary for survival than with political issues.

From Nussbaum's (2003) point of view, capabilities have a very close relationship with human rights. For the author, along with human rights, capabilities provide a rich moral and humanitarian set of goals for human development, claiming that the area covered by both is called "first generation rights" (civil liberty politics) and the second generation rights (economic and social rights). According to the author, these would be the individual capacities central to human development: i) life; ii) bodily health; iii) bodily integrity; iv) feelings, imagination, and thought; v) emotions; vi) practical reason; vii) affiliation; viii) other species (being able to live and having concern for animals and plants); ix) fun; x) political and material participation in the environment.

In contrast to philosophical approaches that focus on happiness and people's desires/satisfaction, for Robeyns (2005), the capabilities approach focuses on the structure of thinking, from a normative point of view. Although Amartya Sen's theory has inspired other studies devoted to understanding different forms of poverty, for Smith and Seward (2009) Sen's ideas on capabilities leave room for misinterpretation. The authors point out that thus, the theses presented by Sen would not fully apply to reality. Some ideas exposed by Sen would be valid only on a theoretical level, and it would not be possible to apply them with complete fidelity to empirical reality, which prevents them from having an immediate application.

The power arising from the freedoms expressed by Sen is associated with the Foucauldian view of power. For Foucault, the idea of power is far beyond dominion over something material or over ideas, but also related to the power to set one's own goals or make one's own decisions. It is power in the most spiritual sense, within each person, such as self-acceptance and self-respect, considering everyone is equal and has the right to freedoms (ROMANO, 2002).

Although subject to criticism, the freedoms set forth in Amartya Sen's approach allow us to conclude that poverty can occur in many different ways and areas of society. Poverty can be a combination of different types of deprivations, experienced under different intensities, making each case unique. According to Codes (2008), it is a complex social phenomenon, which is not only linked to physical and material needs, but is also directly linked to the denial of opportunities and the deprivation of a life within the standards acceptable to society. At some point this deprivation will bring a feeling of powerlessness and insecurity when facing destinies. In other words, deprivation gives people the feeling that it is not possible to have control over their own lives.

In terms of management, the multidimensional approach can offer numerous benefits for the government to develop anti-poverty strategies. Such an approach has greater capillarity and capacity to generate accurate diagnoses of the reality that it intends to analyze and intervene

in. In this sense, Alkire and Foster (2008) point out that there are three main perspectives for identifying a person considered poor in a multidimensional context:

a) The first is called the 'one-dimensional' approach, where different indicators of well-being are combined into a single variable, and thus the person will be considered poor if that dimension is below the estimated line.

b) The second is called 'unity', in which a person is considered multidimensionally poor when he or she suffers some difficulty in some dimension. This approach requires some caution when being analyzed as it can generate exaggerated poverty estimates.

c) The third is the 'intersectional' approach. Here, a person is only considered poor if he or she is deprived in all the dimensions analyzed.

In this study we will make use of the analysis method developed by Alkire and Foster (2009) to perform an *ex post facto* multidimensional analysis of poverty at the local level, after having absorbed a gigantic environmental disaster.

3 METHODOLOGY REFERENCE

3.1 RESEARCH STEPS, SAMPLING PROCESS, AND DATA COLLECTION

This study comprised different methodological steps. The first part of the study comprised a literature search and review on the analysis focus themes, including discussions on the concept of multidimensional poverty, development, and socioeconomic vulnerabilities.

The second step of the research consisted of collecting primary and secondary data for evaluation using the Alkire-Foster Method. Since the study aims to perform a comparative *ex ante* and *ex post* facto analysis of the Fundão Dam disaster in Mariana in 2015, primary data was collected in the municipality and analyzed in the light of secondary data made available by the Brazilian Institute of Geography and Statistics (IBGE). Information from the Mariana municipal census, collected by the IBGE in 2010 (which presents the reality of the municipality before the disaster) was also evaluated.

Primary data was collected using a probabilistic sample. Thus, we randomly interviewed people in different sectors of the municipality of Mariana. At the 10% significance level, the sample size indicated 256 semi-structured interviews (which will represent the economic situation of the inhabitants after the disaster).

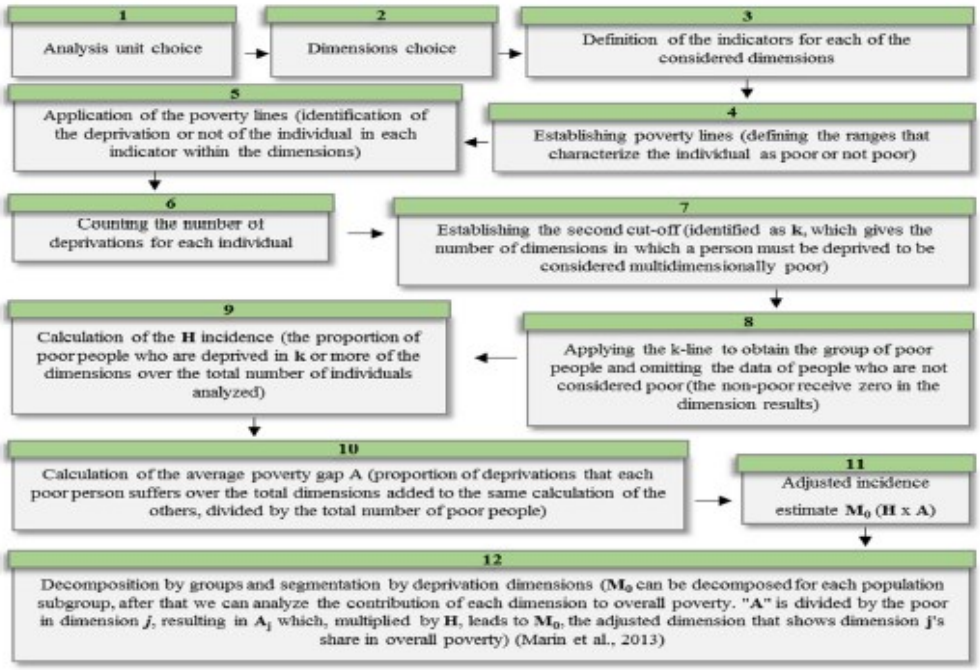
In particular, a questionnaire containing 70 objective/closed-ended questions was applied. The questions aimed to collect information on the population's well-being and life quality. Thus, we questioned the sample regarding their housing conditions, habitability, access to public services, education, and work, among other aspects. The construction of the data collection instrument was based on the format of the questionnaire applied by IBGE in the 2010 Census, with the addition of questions that captured residents' perceptions of the effects of the 2015 disaster on the municipality.

It should be noted that the interviews were conducted in the months of December 2017 and January and February 2018 in the main district of the municipality of Mariana (nomenclature given by IBGE for the urban region of the Municipality). The primary data collection step comprised the questioning of 256 Mariana residents, living in 29 sectors randomly chosen through drawing. Within each sector, data was collected to make up the sample, which meant selecting each household in an order of 3.

3.2 PROCEDURES FOR APPLYING THE *ALKIRE-FOSTER* METHOD

Alkire and Foster (2009) point out that the method makes it possible to measure multidimensional poverty levels in human life from aggregate data. Another advantage that gives credibility to the model is the existence of a double cut-off line, where the first one shows whether the analyzed people are deprived in a certain indicator for each dimension separately. While the second cut-off line consists of the sum of each individual's deprivations. In this case, if this sum is greater than or equal to a certain minimum of deprivations, the individual is considered multidimensionally poor. Figure 1 summarizes the twelve steps for operationalizing the *Alkire-Foster* method.

Figure 1 – Methodological sequence



Source: Alkire and Foster (2009).

Were evaluated the perspective of the living conditions of the population of the municipality of Mariana in Minas Gerais and their housing conditions and access to essential services for the development of their well-being from four major dimensions, entitled: "Health and sanitation", "Housing conditions", "Income and education", and "Occupation". Each of these dimensions is represented by multiple indicators/variables (Table 1).

The selection of proxy variables for access to knowledge, included in the "Income and Education" dimension, was based on the understanding that these are fundamental tools for the creation of possibilities to improve the life quality of individuals and society. Specifically, this dimension comprises the variable "education level", which describes an individual's access to formal education. Thus, individuals who have not completed elementary school will be considered deprived. Another variable analyzed is "Access to knowledge". Considering that the internet is one of the fastest and most practical means of transmitting knowledge, it is assumed that the individual who does not have a computer with internet access at home is deprived. The third variable is associated with "income" and is advocated by Law No. 185 of January 14, 1936, which states that every worker has the right, in payment for the service rendered to a minimum wage capable of satisfying, in a certain region of the country and at a certain time, his normal needs for food, housing, clothing, hygiene, and transportation. Therefore, anyone who does not have a minimum wage is considered to be deprived in the "income" variable. In summary, the influence of access to financial resources on the individuals' ability to have healthier food, better adequate health care, decent and comfortable housing conditions, among other benefits that money and employment can provide to a person.

Table 1 – Dimensions and analysis variables included in the Alkire-Foster method

Dimensions	Variables	Deprived if...
Comforts and Housing Conditions	Type of occupied household	Not a house, town house, condominium or apartment
	State of the occupied household	Not already paid or still in a state of payment
	Predominant material of the household	It is not lined masonry or wood suitable for construction
	Number of people per bedroom	There are more than 3 people living in each bedroom
	Number of bathrooms in the household	No bathroom in the household
	Refrigerator	No refrigerator
	TV	No TV
	Washing machine	No washing machine
	Computer	No computer
	Cell phone	No cell phone
	Radio	No radio
	Automobile	No automobile
	Motorcycle	No motorcycle
	Location of toilet sewage discharge	Not in the general sewage system
Health and sanitation	Water supply	Not by general distribution network
	Garbage collection	It is not collected directly by the cleaning service or by a dumpster
	Electric power	Not through the distribution company
Income and Education	Income	Less than a minimum wage
	Access to knowledge	No computer with internet access
	Highest education level	Have up to elementary school (4th grade)
Occupation	Paid work	Do not have a paid work
	INSS (Social security) taxpayer	Not an INSS taxpayer
	Working hours	Working more than 44h per week
	Returns home daily	Not returning daily to your residence
	Commuting time to work	Commuting time is more than one hour per day

Source: Prepared by the authors based in Santos (2018).

The "Health and sanitation" dimension demonstrates the health conditions and quality of life of Mariana's residents. In order to do so, was analyzed the access to garbage collection and water supply, among other services that are essential for a good life and health quality for

any person. Furthermore, it is worth mentioning this dimension comprises the variables: access to sewage, piped water, garbage collection, and electricity. Those individuals who have: access to adequate sanitary facilities in their homes (a factor that contributes to prevent contamination and diseases from occurring); access to water supply (considering that water is a necessary good for human survival and that its lack can lead to various social, political, and health problems); access to garbage collection services (families that do not have these services are deprived of adequate garbage disposal and are vulnerable to bad smell, disease transmission, and pest and insect infestations); access to electricity (because it is possible to store food, have light, and take a comfortable shower, among other benefits).

The "Occupation" dimension evaluates the influence of the work activity conditions on the individuals' well-being. To operationalize this dimension, we estimate the working conditions, the time dedicated to professional commitments, among other aspects that include the variables: "paid work", "INSS tax contribution", " income earned in the month", "weekly working hours", "daily return to the household after work", and "commuting time from work to the household". Individuals were considered deprived if they: do not have a paid work; do not have a paid work at the time of the interview; do not pay a tax contribution to the INSS; live with an income lower than a minimum wage; have a weekly workload higher than 44 hours (contradicting the legal guarantee to the worker, established by Law No. 13,467, of July 13, 2017); do not return daily to their households after work and/or spend more than one hour a day commuting.

In line with the cut-off criteria defined in this survey, studies point out that physical and psychological problems can derive from individuals' high workload. According to Santos and Cardoso (2010), emotional stress has the ability to make the body more vulnerable to diseases, besides aggravating psychological problems. Thus, people who work more than 40 hours a week (or 8 hours a day) are considered deprived. Considering that the time spent commuting can be a factor in developing anxiety and stress, the longer the commute, the greater the chances of stress. Thus, a person who faces more than 60 minutes between work and home is considered deprived. On the other hand, people who have the opportunity to return home every day after work have daily contact with their family and develop the comfortable feeling of being at home. Therefore, they are not considered deprived.

Finally, the dimension "Comfort and housing conditions" in the *A-F* method aims to evaluate the quality of housing and access to consumer goods, as essential elements for protection, comfort, and well-being. This dimension comprises the following variables: type of occupied household; state of the occupied household; predominant housing material; number of people per bedroom; number of bathrooms in the household, ownership of electrical and electronic equipment (radio, TV, washing machine, etc.). Therefore, individuals who live in adequate housing (such as houses, apartments, or condominiums), whether they own their own homes, have paid for them, or are in the process of paying for them, are considered to be non-deprived. Also, to be non-deprived, individuals must live in adequately structured housing (in masonry material) with bathrooms available.

The number of possessions an individual has, some of which are essential for survival, was also assessed. For example: a stove and a refrigerator, and there are also goods considered luxury, but which are also fundamental for not being deprived, such as television, radio, and computers with internet access. These goods can transmit information, something that is

fundamental to forming opinions and shaping people's behavior. Thus, the individual who does not own goods such as a refrigerator, stove, TV, and washing machine is considered deprived.

In the step of applying the first cut-off line, we established a minimum value for the individual to be considered deprived or non-deprived for the indicators analyzed. This line provides a comparison of the data for all the indicators. As an example, we take a hypothetical situation where there are variables representing the "Occupation" dimension for 5 people (Table 2 and 3).

Table 2 – Simulation of the model to analyze the "occupation" variable

Occupation					Analyzed Individuals
Paid work	INSS (Social security) taxpayer	Working hours	Returns home daily	Commuting time	
Yes	No	40h	No	30 min	Individual 1
Yes	Yes	44h	Yes	60 min	Individual 2
No	No	55h	No	120 min	Individual 3
Yes	No	30h	No	15 min	Individual 4
Yes	Yes	46h	Yes	20 min	Individual 5

Source: prepared by the authors based on hypothetical data.

The letter D is used to characterize a deprived individual in the first cut-off line, otherwise a non-deprived individual is represented by the letters ND (VIEIRA et al., 2017). In the paid work item, the agent is deprived if (x = has no paid work); INSS taxpayer if (x = does not pay tax contribution to INSS); working hours (x > 44 hours per week of work); returning home daily (x = does not return home daily); commuting time (x > 30 minutes of commuting). Then we have:

Table 3 – Transformation of the variables into initial indicators

Occupation					Analyzed Individuals
Paid work	INSS (Social security) taxpayer	Working hours	Returns home daily	Commuting time	
ND	D	ND	D	ND	Individual 1
ND	ND	ND	ND	D	Individual 2
D	D	D	D	D	Individual 3
ND	D	ND	D	ND	Individual 4
ND	ND	D	ND	ND	Individual 5

Source: prepared by the authors based on hypothetical data.

After the first cut-off, the sixth step of the *A-F* method comprises counting how many deprivations each individual in the population/sample has. In order to do so, we replace D by 1 and ND by 0. Such that the matrix previously shown is rewritten as:

	Dimensions					Sum of deprivations	
X =	0	1	0	1	0	2	Individual 1
	0	0	0	0	1	1	Individual 2
	1	1	1	1	1	5	Individual 3
	0	1	0	1	0	2	Individual 4
	0	0	1	0	0	1	Individual 5

With the sum of the number of deprivations per individual in the population/sample, a minimum number of deprivations must be established for the person or family to be classified as multidimensionally poor or not. Alkire and Foster (2009) and Fahel *et al.* (2016) suggest the value of 1/3 deprivation as the minimum criterion for an individual to be classified as multidimensionally poor. This same criterion was adopted in the present evaluation.

The application of the second cut-off line consists in aggregating the deprivations and establishing the level of multidimensional deprivation. Following the previous example ("Occupation"), one third of five dimensions equals 1.67, so anyone with two or more deprivations is considered multidimensionally poor. Therefore, individuals 1, 3, and 4 are deprived.

According to Alkire and Foster (2009), the calculation of incidence and average poverty gap can show the proportion to which people or households are deprived. The gap shows the average fraction by which individuals are deprived, so that the intensity of poverty can be identified. Its estimate is given by:

$$H=\frac{q}{n} \quad (1)$$

Where: $\boldsymbol{q}$ = the number of multidimensionally poor people; and $\boldsymbol{n}$ = total number of people in the sample.

On the other hand, the adjusted incidence calculation can show how much deprivation the multidimensionally poor population suffers and how much they have the capacity to suffer. In other words, this population is considered extremely poor or not very poor. Its calculation is based on (ALKIRE; FOSTER, 2009):

$$A=\frac{\sum_{i=1}^{n} C_i(k)}{q} \quad (2)$$

Where: $\boldsymbol{C_i\ (k)}$ = Number of deprivations of the individual; and $\boldsymbol{q}$ = number of multidimensionally poor people.

In the measurement decomposition step of the *A-F* method, the samples were decomposed by group, age, gender, neighborhood or any other group analyzed. The decomposition can also be done by poverty dimensions (ALKIRE; FOSTER, 2009):

$$M_0 = H\,x\,A \quad (3)$$

Substituting in (1) the expressions referring to the proportion of people Deprived (H) and intensity of deprivation (**A**), we have:

$$M_0=\left(\frac{q}{n}\right)\ x\ \left(\frac{\sum_{i=1}^{n} C_i(k)}{q}\right) \quad (4)$$

The *Alkire-Foster* multidimensional poverty analysis method allows the poverty level to be calculated quickly and easily, and robust diagnoses can be generated succinctly and reliab.

4 ANALYSIS AND DISCUSSION OF THE RESULTS

In order to analyze the socioeconomic transformations resulting from one of the biggest environmental disasters in the modern world – the Fundão dam collapse in Mariana/MG/Brazil – we estimated the multidimensional poverty index using the Alkire-Foster method. Table 4 presents the re

Table 4 – Results from applying the Alkire-Foster method to Mariana (MG)

Analysis period	Incidence Calculation (H)	Average Poverty Gap Calculation (A)	Adjusted Incidence (M)
2010	0.045	0.015	0.0007
2018	0.172	0.061	0.0105

Source: Prepared by the authors based on primary data collected and the 2010 Census database.

The population considered to be multidimensionally poor in Mariana represented 4.5% of local residents in 2010. Whereas in 2018, the percentage of poor people grows to about 17.2% of the sample selected for analysis. The result of the average poverty gap (A) captures the intensity of poverty, considering the dimensions analyzed, how many indicators on average the poor are deprived of. Thus, in 2010, the multidimensionally poor people living in Mariana were deprived in 1.5% of the variables analyzed. The average deprivation fraction rises to 6.1% in 2018.

After calculating the poverty incidence (H) and the Average Gap (A), it is possible to measure the Adjusted Incidence (M), which serves as an indicator for the poverty level. The closer to 100% the result of M is, the higher the proportion of deprivations that the poor population faces compared to the maximum deprivations that the entire population could suffer (VIEIRA et al., 2017). The estimated result indicates that 0.07% of the local population experienced deprivation in 2010. In 2018, this indicator points to about 1.05% of the analyzed sample susceptible to deprivation.

The results of our analysis corroborate with the impacts of the Fundão dam collapse on socioeconomic activities pointed out by Freitas et al. (2016). These authors identified damages that directly affected essential public services, such as the lack of power generation and distribution, services responsible for approximately 40% of total economic losses. The lack of public services for sewage treatment, public health, urban cleaning and waste disposal, transportation and education were also affected the population of Mariana. According to Freitas et al. (2016), the private sector absorbed economic losses in the order of R$253 million, concentrated mainly in industrial activities (84% of the total).

According to a report by the Getúlio Vargas Foundation (2020), the loss of aggregate income extended to the state of Minas Gerais and Espírito Santo, jointly, totaling R$136.28 billion in the period corresponding to 2015 and 2017, with 92.9% concentrated in the total remuneration of labor income (46.11%) and capital (46,75%). The remaining R$ 9.72 billion (7.1%) comes from the loss of income from the land factor. Regarding the employment analysis, it was found that 420 thousand people became unemployed in 2015 (FUNDAÇÃO GETÚLIO VARGAS, 2020).

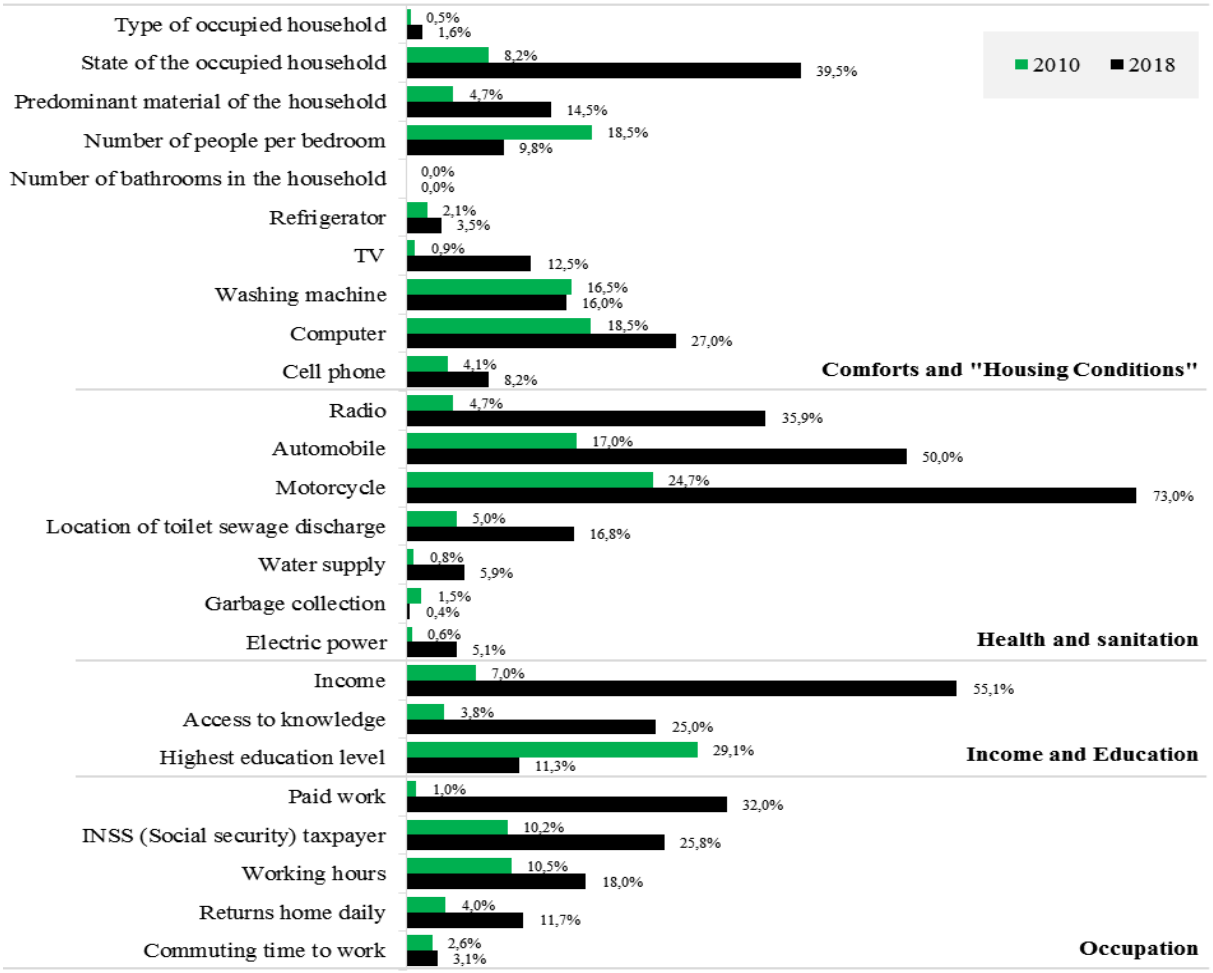
The retraction of the tax base after the abrupt stoppage of mining activities of the company Mineração S/A the company that operated mining in the area where the dam was ruptured) caused collapse not only in the local economy, but also in the region (FREITAS et

al., 2016). In addition to environmental issues, economic systems that are not very diversified are extremely fragile from the point of view of sustainable development, as in this case in which 95% of the economic activities of the municipality of Mariana were based on iron ore extraction (MINAS GERAIS, 2016).

It is also estimated that there were losses exceeding R$ 20 million in the primary and extractive sectors. It is worth noting that part of the resources provided by these sectors, especially when they provide subsidies for the local population's self-consumption, usually do not enter the official economic statistics. The trade and services sectors also recorded direct losses, in addition to indirect losses influenced by reduced tourism and purchasing power, with a downward trend in sales for extended periods (FREITAS et al., 2016).

It can be seen that the level of deprivation increased significantly for most of the variables analyzed in our model (Figure 2). For 2010, the percentage of deprived individuals was higher among the variables related to education and ownership of consumer goods. In 2018, deprivations were more recurrent for the possession of consumer goods, the state of the occupied household, and to income generation.

Figure 2 – Recurrence of deprivations by A-F method analysis indicator for 2010 and 2018



Source: Prepared by the authors based on data from the on Demographic Census (2010) and interview data (2018).

Analysis of the variation in deprivations between 2010 and 2018 indicates that there has been improvement in the living conditions of Mariana residents in only four of the twenty-five variables observed. Notably, the ownership of a washing machine has become popular in the municipality and the density of people living in the same household has decreased. It is also worth noting that the conditions of access to garbage collection and education have been expanded in the last eight years.

Above all, the deprivations after the collapse of the Fundão dam intensified especially for the variables: TV (1,287.2%), income (687.48%), radio (657.94%), and access to knowledge (550.98%). In 2018, 55% of the surveyed individuals had an income of less than one minimum wage. Furthermore, 32.03% of the residents sampled from Mariana had no paid work.

In relation to the Demographic Census (2010), 1,357 did not finish the final stages of basic education. A significant part of Mariana's population is also deprived of access to their own means of transportation, such as cars and motorcycles. In addition, it can also be seen that 864 individuals lived in households with bedrooms occupied by more than 3 people and in 861 households there was no owned computer available.

In another way, the biggest deprivations identified in 2018 the dimensions presenting the highest indexes of deprivation were "Comforts and Housing Conditions" and "Occupation". In summary, 187 individuals do not own a motorcycle, 141 do not earn at least one minimum wage and 128 people stated that they do not own a car. The number of people who reported being deprived of access to employment (about 32% of the sample) is remarkable. The figure is three times the state average, where the unoccupied rate is 10.6% (IBGE, 2017).

Considering the results presented, we infer that important economic vulnerabilities have emerged following the accident at the mining site in the Bento Rodrigues district. Among the immediate consequences for the Mariana population is the growth of the unemployment rate, the drop in per capita income, and the institution of negative expectations regarding the exploration of mining activity in the region.

It is also worth mentioning that the ability of local public authorities to respond to the population's demands after the disaster was restricted, especially because of the significant drop in revenue generation. For illustration purposes, in July 2015, the amount collected by the Municipality of Mariana in taxes was R$ 278,252,735.13. Meanwhile, in July 2018, the total taxes collected were R$ 142,008,337.31, representing a 49% decrease in municipal revenues for the same period in 2015 (MARIANA MUNICIPAL GOVERNMENT, 2018).

Thus, Sen (2000) states that when instrumental and individual freedoms are deprived, society will tend to experience moments of stagnation in the development process, from a social and economic perspective. In fact, the analysis of Mariana's contemporary reality indicates that challenges regarding life quality promotion will be part of the political and academic agenda in the coming years.

5 FINAL CONSIDERATIONS

The Fundão dam disaster in Mariana has been called the biggest environmental disaster in Brazil's history, generating significant environmental and social losses. Part of the Atlantic Forest was impacted, as well as regional and national aquatic ecosystems. The reflexes on the capacity for social reproduction of the cities of Minas Gerais also add up to significant negative externalities.

Primary data collection, conducted through sample interviews of residents in that municipality, and the analysis of Demographic Census data, revealed that multidimensional poverty grew between 2010 and 2018 in Mariana. According to the calculations used in this analysis, the incidence of poverty in 2018 was almost four times (3.8) higher than the incidence of poverty found in 2010.

The estimation of the *Alkire-Foster* method indicated that in the "Comforts and Housing Conditions" and "Occupation" dimensions the Mariana residents have higher deprivation levels. The results of the survey show a worrying scenario. One in three interviewees does not have a formally paid job. This means that a significant portion of the population faces difficulties entering the job market or maintaining a stable occupation. Informality, unemployment and job insecurity are challenges that affect the quality of life and dignity of these people. In addition, more than half of those interviewed face a reality of insufficient income - less than the minimum wage - to meet basic needs such as food, housing and health. This data reveals the financial fragility of many families living in the municipality of Mariana.

The poorer living conditions in the current year make us believe that the incident at the mining dam has asserted many different socioeconomic vulnerabilities. Therefore, public and private entities will be invited to intervene in regional development processes. Projects that foster job and income generation and improve the population' life quality will certainly be demanded by the municipality's residents.

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AGRADECIMENTOS E INFORMAÇÕES

Agradecemos à Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES, pela bolsa de mestrado utilizada para a realização desta pesquisa.

Esta pesquisa foi avaliada e aprovada pela Comissão Nacional de Ética em Pesquisa por meio do certificado CAEE: 81127317.0.0000.5346.