Research, Society and Development, v. 9, n. 4, e80942517, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i4.2517

Rompimento de barragem e direito à moradia adequada: perspectivas do maior desastre socioambiental do setor de mineração Brasileiro

Dam collapse and right to adequate housing: insights from the biggest socio-environmental disaster involving Brazilian mining sector

Falla de la presa y derecho a una vivienda adecuada: perspectivas del mayor desastre socioambiental en el sector minero Brasileño

Recebido: 05/01/2020 | Revisado: 06/02/2020 | Aceito: 12/03/2020 | Publicado: 20/03/2020

Juliano Scarpelin
ORCID: https://orcid.org/0000-0003-4771-9381
Universidade Federal de Ouro Preto, Brasil
E-mail: juscarpflorestal@gmail.com
Lário Moisés Luís Herculano
ORCID: https://orcid.org/0000-0003-2772-8141
Universidade Federal de Ouro Preto, Brasil
E-mail: lario.zualo@gmail.com
Lívia Cristina Pinto Dias
ORCID: https://orcid.org/0000-0001-7797-8574
Universidade Federal de Ouro Preto, Brasil
E-mail: livia.dias@ufop.edu.br
Vitorino Fernando Chume
ORCID: https://orcid.org/0000-0002-0882-6056
Universidade Federal de Ouro Preto, Brasil
E-mail: vitorino.chume@aluno.ufop.edu.br

Resumo

Em 2015, a barragem de Fundão se rompeu e destruiu comunidades rurais em Mariana-MG. A reparação para as comunidades atingidas em Mariana foi definida em sede de Ação Civil Pública, que estabelece o Reassentamento Familiar como um dos meios de reparação da violação direito à moradia. Nosso objetivo foi comparar dados das propiedades atingidas com os parámetros de reparação. Dados das propriedades rurais atingidas foram comparados com os parâmetros de reparação, revelando que 65,7% das 102 propriedades rurais com rejeitos de mineração possuem menos que o Módulo Fiscal de Mariana, 20 ha, tamanho mínimo para que propriedades rurais sejam consideradas economicamente viáveis. Para

garantir a viabilidade econômica de novas propriedades, parâmetros de reparação devem ser determinados. Recomendamos a compensação adicionando um Módulo Fiscal à área de destino e a implementação de acordos e orientações para reparação por meio do projeto de Política Nacional sobre os Direitos das Populações Afetadas por Barragens.

Palavras-chave: Rompimento de barragem de rejeito; Compensações; Reassentamento Familiar.

Abstract

In 2015, the Fundão dam broke and destroyed rural communities in Mariana-MG. The reparation for the affected communities in Mariana was defined in the Public Civil Action, which establishes Family Resettlement as one of the means of reparation for the violation of the right to housing. Our goal is to compare the data of rural properties affected witch the reparation parameters. Data from the affected rural properties were compared with the repair parameters, revealing that 65.7% of the 102 rural properties affected by mining waste have less than the Mariana Fiscal Module, 20 ha, a minimum size for the rural properties to be considered economically viable. To ensure the economic viability of new properties, reparations parameters must be determined. We recommend compensation by adding a Fiscal Module to the destination area and implementing agreements and guidelines for redress through the draft National Policy on the Rights of Populations Affected by Dams.

Keywords: Tailing dam rupture; Compensatory measures; Family Resettlement.

Resumen

En 2015, la presa Fundão quebró y destruyó comunidades rurales en Mariana-MG. La reparación para las comunidades afectadas en Mariana se definió en Acción Civil Pública, que establece el reasentamiento familiar como uno de los medios para reparar la violación del derecho a la vivienda. Nuestro objetivo fue comparar los datos de las propiedades afectadas con los parámetros de reparación. Los datos de las propiedades rurales afectadas se compararon con los parámetros de reparación, revelando que el 65.7% de las 102 propiedades rurales afectadas por los realves mineros tienen menos que el Módulo Fiscal Mariana, 20 ha, tamaño mínimo para que las propiedades rurales sean consideradas económicamente viables. Para garantizar la viabilidad económica de las nuevas propiedades, se deben determinar los parámetros de reparación. Recomendamos una compensación agregando un Módulo Fiscal al área de destino e implementando acuerdos y pautas de reparación a través del marco de la Política Nacional sobre los Derechos de las Poblaciones Afectadas por las Presas.

Palabras clave: Ruptura de presas de relaves; Compensaciones; Reasentamiento familiar.

1. Introduction

Mining is important to any society because it offers industrial raw materials, contributes to job creation and boosts the economy. On the other hand, it has negative impacts such as

deforestation, noise pollution, change in air quality, contamination and soil compaction, contamination and pollution of water resources, the latter mainly caused by tailings dam ruptures (Banco Mundial, 2003).

Worldwide, there are over 56,000 mining tailings dams (Burritt & Christ, 2018) of which 740 are in Brazil (Lempriere, 2019). Brazilian mining tailings dams was featured in the news and much scientific research after the recent ruptures that occurred in Mariana in 2015 and Brumadinho in 2019, both in the state of Minas Gerais (MG), corresponding respectively to the largest in length and loss of human life in Brazil. Despite their expressiveness, Brazilian disasters are only the latest in a series of catastrophic tailings dam disruptions around the world. Santamarina et al. (2019) reported that there were dam ruptures in Mexico, Bulgaria, Italy, Philippines, China and Canada in the last 100 years, which totaled almost 3000 human losses.

On November 5, 2015, the Fundão dam (Samarco - Vale - BHP Billiton) broke up in Mariana-MG. This rupture is considered one of the biggest technological disasters in the country (Zhouri et al., 2016) and it has launched more than 45 million cubic meters of tailings on the Doce River. The mining tailing left a trail of destruction through the 663.2 km of waterways traveled until the coast and reached the states of Minas Gerais and Espirito Santo, the longest distance traveled by mining tailings in South America (Fernandes et al., 2016). According to the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA, 2015), it is impossible to estimate the recovery time of the site, due to the impact of the destruction it has reached.

The disruption of the Fundão dam first reached a sub-basin of the Rio Doce called Gualaxo do Norte basin, which covers an area of about 19,805 hectares (Rodrigues, 2012) and has an estimated population of about 67,819 inhabitants (IBGE, 2010). In Mariana, the affected population is distributed in eight affected communities, two of which are in the process of collective resettlement, while the other six remain in affected territories (Cáritas, 2017).

The Mariana-MG and Brumadinho-MG disaster in 2019 alerted to the need for Brazil to determine criteria and actions to repair the communities affected by this type of disaster. Existing compensation and resettlement criteria, draft laws, and prior court decisions are related to hydroelectric dams, which have been implemented for the purpose of energy supply and exploitation since 1970 (Derroso & Ichikawa, 2014). In hydroelectric plants, these criteria were defined before the installation of the projects and allowed time for decision making and negotiation, unlike the emergency situation experienced by the populations affected by mining disasters.

In Mariana-MG, the reparation process is defined by the local Public Civil Action.

Among the various remedies approved in the Public Civil Action, we highlight the right to family resettlement defined by the "Right to Housing Remediation Guidelines" and object of interest for the resettlement of the six communities not covered by collective resettlement. The Family Resettlement modality comes from the organization and claim of those affected from the six rural communities, who claimed the homologation of the reparation modality (Cáritas, 2017). Agreements approved in guidelines state that Family Resettlement must guarantee access to properties with characteristics equal to or greater than those achieved. The agreements state that, in the impossibility of guaranteeing properties with equal characteristics, families should be compensated. Despite the approved agreements and guidelines, no affected families were repaired through the Family Resettlement modality in rural property until April 2019 (MPMG, 2019).

Many groups in Brazil and around the world have studied the environment (Fernandes et al., 2016; Marta-Almeida et al., 2016; Segura et al., 2016) and social (Aleixo & Bastos, 2018, Viana, 2017, Zhouri et al., 2016) effects of this mining disaster. This study aims to contribute to the discussion of the interaction between the environmental disaster and the right of the affected population to decent housing. Specifically, we (i) discuss the dependency relationship between the affected population and natural resources; and (ii) we analyzed the data of rural properties affected by the deposition of tailings of Fundão dam and compared with the reparation parameters adopted by the parties for resettlement and family compensation.

2. Context of the Fundão dam rupture and its environmental and socioeconomic consequences

According to Freitas, Silva & Menezes (2016), Fundão's disaster is the largest in terms of the amount of material released to the environment and the territorial extent of its damage. The flow rate was over 45 million cubic meters of tailings from the iron ore beneficiation process (IBAMA, 2015), while those recorded in the Philippines was 28 million cubic meters in 1982 and 32.2 million cubic meters in 1992 (Fernandes et al., 2016).

There is still no consensus among academics about what would have caused such a disaster, but there are some hypotheses related to the increased rate of tailings deposition. Between 2009 and 2014, the rate of tailings dumping increased by 83%, a factor that would contribute to the destabilization of the dam (Freitas, Silva & Menezes, 2016).

The break left a trail of destruction along the 663.2 km of waterways traveled between Minas Gerais and the coast of Espírito Santo. The mud destroyed vegetation, soil, biodiversity and protected areas, and affected water quality and geomorphology at local and regional scale.

The mining tailings affected approximately 1469 ha of natural vegetation and 90% of the watercourses' riparian habitats (Fernandes et al., 2016) caused widespread loss of ecological services and loss of transitional earth-water connectivity. As for the soil, the disaster caused erosion, compaction and contamination by metals and amines (Coelho, 2015). The tailings stream buried aquatic and riparian habitats, eliminating much of the regenerative capacity of aquatic and terrestrial ecosystems (Fernandes et al., 2016) with loss of biological importance for conservation. The dam rupture affected the water quality, mainly in the turbidity parameter. Excess turbidity may have caused the deaths of thousands of fish and other aquatic organisms at first. Then, the drop in photosynthetic activity of algae and other aquatic plants compromised the functioning of the entire trophic chain (Coelho, 2015). This has affected economic activities from agriculture and fishing to mining itself and other services.

Although Mariana's main activity is mining, agriculture is known to contribute to the region's economy. Most of the damage occurred in plantation areas, mainly sugar cane, grains and vegetables (Cruz & Domingues, 2017). Another productive activity that was harmed in Mariana-MG is the dairy farming. In Mariana-MG, the predominant dairy production system is pasture fed cattle. However, the disaster resulted in loss of pasture area and restriction of access to water resources in properties that had accumulated tailings. Producers who remained in the affected areas suffered a forced change of management in their dairy production systems: from pasture fed cattle to semi-confinement or total confinement cattle. The change in the management of the pasture system, which requires the consumption of silage, results in increased demand for labor to the affected producers. In addition to the increase in labor costs, farmers have reported the increase in the incidence of foot diseases (hoof problems caused by infection, such as lameness). These diseases are frequent in confined dairy herds (Greenough & Weaver, 1997, Souza, 2002) and result in reduced milk production, reduced reproductive capacity, loss of milk (through drug use), early disposal and investment in the treatment of sick animals (Shearer et al., 1996, Stanek, 1997). The Minas Gerais Task Force Report (2015) estimated losses on agricultural and livestock activity to the order of R$1.9 and R$21.3 million respectively. Producers had no prior solutions, and some still have high-value rural credit financing with no prospect of repayment (Cruz & Domingues, 2017). Families also suffered from the loss of fishing activity, which was practiced as an alternative and complement to the self-consumption of families, although not described as income generating activity (Viana, 2017).

On infrastructures, Freitas, Silva & Menezes (2016) state that the mud caused the destruction of 389 housing units, 2 public health facilities and 6 educational facilities, bridges, roads, and other urban equipment, most of them in Mariana-MG.

In addition to socio-economic and environmental damage, the disruption has caused human loss and various health problems. There were 19 deaths, most of them in the Bento Rodrigues, which is a district of Mariana (Cruz & Domingues, 2017), and many victims have depression, respiratory, eye and skin disorders, and gastrointestinal diseases after the mining disaster (Vormitagg, Oliveira & Gleriano, 2018). The recent publication of Dos Reis et al. (2019) showed concerns about abundance of metals / semimetals in North River Gualaxo because of the positive correlation between human adenovirus and concentration of metals / semimetals.

It is impossible to estimate the return period of fauna and other ecosystems in the affected territory. However, it is undeniable that the recovery of the affected areas must be comprehensive, with concrete actions to remedy the state of absolute need of the affected populations (Barbosa et al., 2015).

With all the data and considerations we agree on the extent of the damage. The repair of the affected families' livelihoods is urgent. In the next section, we will present the measures to repair the right to housing adopted in Mariana-MG.

2.1. The resettlement process in Mariana-MG

All affected communities in Mariana-MG have resettable populations through resettlement. In this case, resettlement is involuntarily classified as defined by the International Finance Corporation (IFC, 2012b), since affected people have been compulsorily relocated to new areas and/or have had restrictions on their land use.

According to a report by Ramboll (2017), infrastructure and housing remediation actions are of an emergency nature, insufficient in the analysis and information on the different types of risks that result in interventions in flooded areas. The reparations actions proposed to the families that did not fit in the collective resettlements by the mining companies was the reconstruction of the housing in the land hit by the tailings mud. Families claimed the right to Family Resettlement, a resettlement modality for allocation of each family nucleus in a property of their choice (Cáritas, 2017).

The choice and criteria for resettlement and reconstruction were defined in agreements called "Housing Right Redress Guidelines". The Housing Right Redress Guidelines were approved at hearings in the "Public Civil Action: MPMG v. Samarco S/A, Vale S/A and BHP

Billiton Ltda. Case No. 0400.154335-6, 2nd District Court of Mariana" and resulted from the negotiation between the claims of the affected communities and the commitment made by the companies. With the approval of the Guidelines, several topics of discussion remain pending among those affected, their technical advice and the companies responsible for repair (MPMG, 2018). One of these themes, provided for in guidelines, is the need for compensation as a means of redress when the original situation cannot be reproduced. The proposal to ensure compensation, even if not defined, aimed at future claims to cases in which the dimensions of use and occupation of the original dwellings were not guaranteed in resettlement and reconstruction. The following are the two guidelines, and their approval dates, which concern the compensations (free translation):

> *If it is not possible to maintain the same or superior characteristics of the buildings (urban or rural) rebuilt or in resettlement, compensation should occur in size of area, or in payment, or improvements in buildings and /or improvements at the choice of family, provided that they are properly supported by technical reports; (02/06/2018).* (TJMG, 2018)
>
> *For the restitution of rural and urban properties, Samarco, Vale and BHP Billiton, through the Renova Foundation will ensure, except when proven to be technically unfeasible, to the collective or family resettlement member, that the new property retains characteristics similar or superior to original property - situation prior to the Fundão dam collapse - especially in the following aspects and without prejudice to others brought by current technical norms:*
>
> *1) topography and agricultural suitability or land use capacity,*
>
> *2) dimensions of the property,*
>
> *3) neighborhood and community relations and*
>
> *4) access to sources of abstraction and use of water.*
>
> *If it is not possible to maintain the same or superior characteristics of the properties, the affected may opt for compensation, as approved at the hearing on February 06, 2018; (3/27/2018).* (TJMG, 2018).

International corporations advise that for losses that are difficult to evaluate, compensation in kind or resources of equal or greater value that can be sustained by the community is ideal (IFC, 2012a).

Despite international guidelines and guidance up to October 2019 no compensation measures were approved. The agreements made and the consulted reports motivated the publication of this article in the expectation of contributing to a fair reparation.

2.2. Resettlement legal aspects of dam-affected populations

In Brazil, there is no specific legislation related to the process of repairing the damage and losses resulting from dam disruption, there are only bills. Until 2015, the bills were directed only to populations affected by construction of hydroelectric water dams. The impacts of hydroelectric water dams, as opposed to tailings dam disruption, are widely known and discussed and the activity has displaced more than one million people in Brazil (Zhouri & Oliveira, 2007). With the disruption of tailings dams in the state of Minas Gerais (Mariana and Brumadinho), deputies proposed a new bill (*Projeto de Lei* or PL, in Portuguese) entitled "PL 2.788/2019" in light of previous projects, with the inclusion of populations affected by tailings dams.

According to Brasil (2019), PL 2.788/2019 specifies the responsibilities of entrepreneurs regarding rights and remedial measures for Populations Affected by Dams. The rights of the Populations Affected by Dams (*População Afetada por Barragem* or PAB, in Portuguese) was defined in the Article III in the PL 2.788/2019 and, in the Article IX, there is a modalities of resettlement guide (free translation):

> *IX - Rural resettlement, observing the Fiscal Module, or urban resettlement, with housing units that respect the minimum size established by the urban legislation.*

The main objective of the PL 2.788/2019 is to provide legal basis for populations affected by dams either by their construction, operation and decommissioning or by the leakage or disruption of these structures (Brasil, 2019). Despite its relevance, the project is awaiting approval and has no guaranteed application. The delay in approving this bill runs counter to the conclusions and recommendations as set out by Randell (2016), who in his study on the Belo Monte hydroelectric power plant case, reinforces that resettlement programs must address the needs of the affected public for its effective resumption of lifestyles.

We agree that resettlement programs must address the needs of the affected public. Our research allows us to reinforce this statement, as will be presented in the next sections.

3. Data and Methods

This article is of a qualitative and quantitative technical character. In addition to the literature review, with information dated from 2001 to 2019, an analysis of the repair parameters adopted for the Family Resettlement modality was performed. The discussion was conducted with data obtained through analysis and classification of the size of the properties affected by the deposition of tailings, family resettlement liabilities, located along the Gualaxo do Norte River in Mariana-MG.

To define the properties analyzed, geospatial data were used, resulting from the self-declaration of the dimension of the rural properties, obtained through the SICAR (National System of the Rural Environmental Registry). SICAR is a Federal Government platform that manages the environmental information of rural properties, where each farmer declares the limits, size, water resources and status of Permanent Preservation Areas and Legal Reserve of his property. Through the platform were obtained the locations and dimensions of all rural properties declared in the municipality of Mariana-MG.

To define which properties would be analyzed, we used geospatial data from IBAMA (Brazilian Institute of Environment and Renewable Natural Resources), corresponding to the tailings deposition area of the Fundão dam rupture. The crossing between Mariana's rural properties and the tailings disposal area gave rise to the first screening of real estate affected in the territory.

From the survey of the properties, the data were organized through the dimension of the properties. For this, we use the concept of Fiscal Module. Fiscal Module is a unit of measure, in hectares, whose value is set by the National Institute of Colonization and Agrarian Reform - INCRA for each municipality. This value is defined by the predominant type of exploitation in the municipality, the income obtained from this exploitation, other activities relevant to land use and the concept of "family property" (INCRA, 2008). The concept of Fiscal Module was introduced by Law No. 6,746/1979, the value of which expresses the minimum size required for a rural property to be considered economically viable (Landau et al., 2012). The value of the Fiscal Module fixed for Mariana-MG is 20 ha (INCRA, 2013).

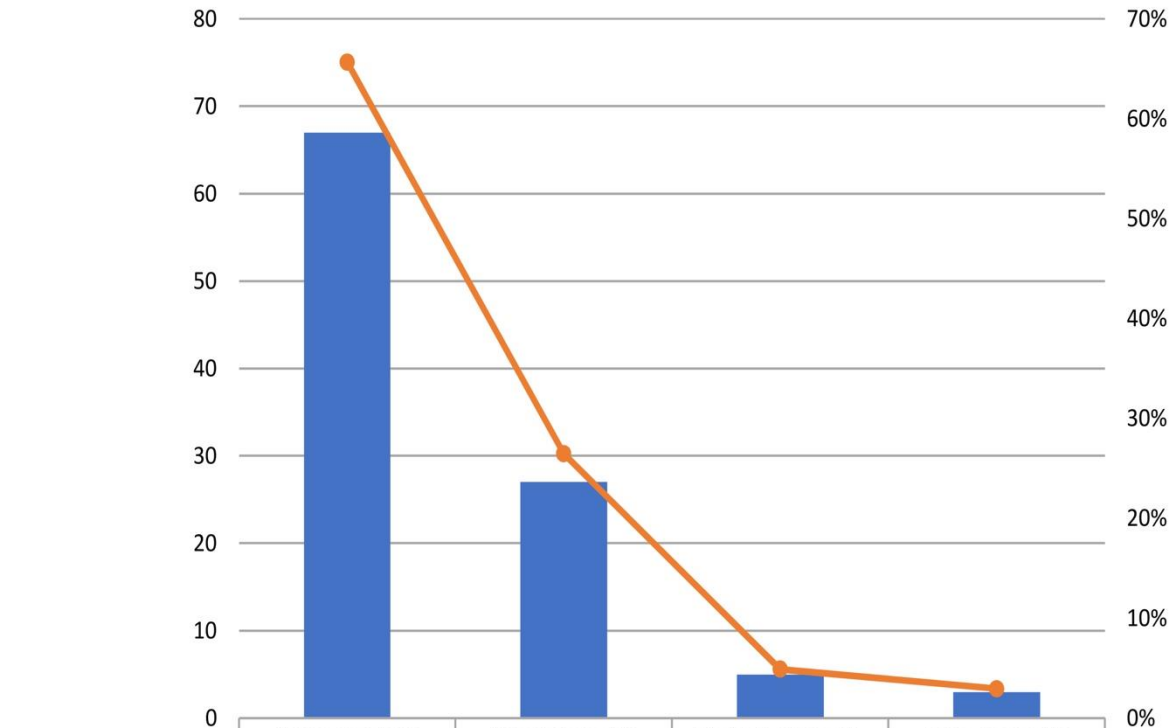
The use of the Fiscal Module for the classification of rural properties is present in Law 8,629/1993 (Art. 4, II and III), in the definition of small property (property with an area between 1 and 4 Fiscal Modules) and medium property (property more than 4 and up to 15 Fiscal Modules). With these definitions, it is understood that the micro-size farm is the rural property with an area of less than 1 Fiscal Module and the large property is one with an area of more than 15 Fiscal Modules (EMBRAPA, 2012). From these definitions the properties analyzed were classified into micro-size farms (with area less than 20 ha), small property

(properties with area between 20 and 80 ha), medium property (property with area between 80 to 300 ha) and large property (with area greater than 300 ha).

4. Findings and Discussion

The farms affected are classified into de categories described in the last section, micro-size farms (with area less than 20 ha), small property (properties with area between 20 and 80 ha), medium property (property with area between 80 to 300 ha) and large property (with area greater than 300 ha). The Figure 1 illustrates the distribution of the data in the categories found in the survey.

Figure 1 - Distribution of farms dimensions affected by tailing deposition in Mariana-MG



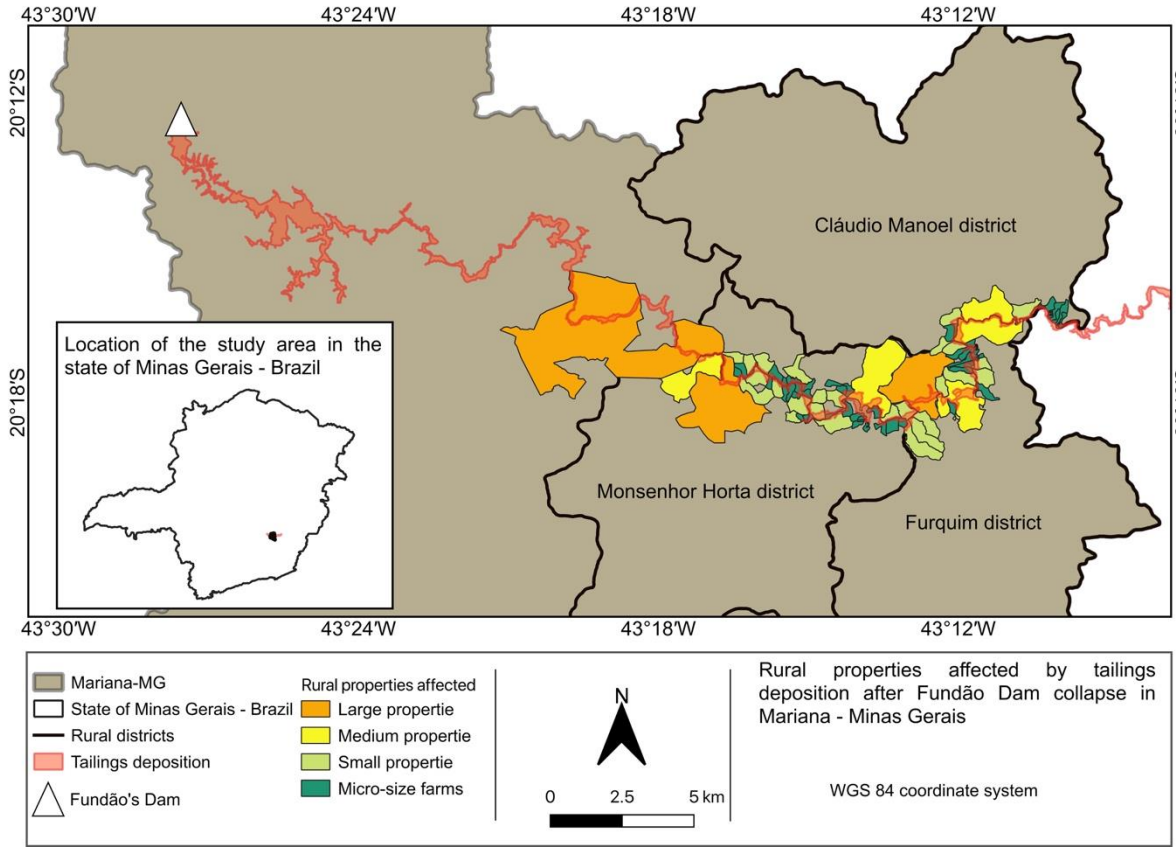
	Micro-size farm	Small propertie	Medium propertie	Large propertie
Number of farms	67	27	5	3
Frequency	65.7%	26.5%	4.9%	2.9%

Font: Scarpelin et al. (2019)

From the data survey, it was found that 65.7% of rural properties affected by the deposition of tailings correspond to micro-size farms, that is, properties with an area smaller than one Fiscal Module. The properties considered small properties correspond to 26.5%, medium properties correspond to 4.9% and large properties correspond to about 2.9% of the total properties affected by the mining tailing.

The information used in Figure 1 can be viewed in its geographic distribution in Figure 2. Figure 2 shows the geographic distribution of the farms affected by the tailings deposition in rural districts of Mariana-MG.

Figure 2 Farms Affected by tailing deposition after Fundão Dam collapse



Font: Scarpelin et al. (2019)

In Figure 2 we can see the expressive presence of small properties and micro-size farms in the three rural districts defined for the study. Most farms are identified as micro-sized farms in this map.

The Fiscal Module expresses the minimum size required for a rural property to be considered economically viable. Then, the diagnosis that the majority (65.7%) of the properties affected by the tailings deposition has an area smaller than this unit of measure draws attention to the proposed remediation measures since resettlement and reparation must guarantee rural properties economically viable to the affected families. Under the revised agreements, companies (Vale, BHP Billiton and Samarco) commit to repay rural properties through Family Resettlement, so that the new property retains similar characteristics or superior to the original property. The agreement further defines that the following characteristics should be reproduced: (i) topography and agricultural suitability or land use capacity; ii) dimensions and tested of the property; iii) neighborhood and community relations and iv) access to sources of water

abstraction and use. In the impossibility of reproducing the same or superior characteristics of the real estate, the affected person may opt for financial compensation or on land.

Despite the agreements, the population affected claim for the approval of the compensation proposal. Until October 2019, the companies responsible for the remedy merely presented arguments and proposals for financial compensation, while that population affected claim compensation in kind (agricultural land) to ensure the maintenance of their livelihoods. Compensation for Family Resettlement is needed, as land and conditions under which families will be resettled will not necessarily have characteristics equal to or greater than land of origin (Aleixo & Bastos, 2018). In addition, the international guidance for hard-to-assess losses and damages is compensation through assets or resources that can be sustained and managed by the community (IFC, 2012a).

Leaders of rural families claim compensation by adding a Fiscal Module to the destination area. The proposal was presented to companies in May 2019 and rejected by the companies. Due to the involuntary departure from their lands, due to the productive impacts, it is reasonable that each Family Resettlement should receive at least the addition of one Fiscal Module to its restitution area as compensation so that the new property will be economically viable for its effective resumption of lifestyles. In addition agreements made and translated into "Housing Right Redress Guidelines" should be adequately implemented.

The absence of specific remediation rights legislation for Dam Affected Populations creates a situation of vulnerability and allows entrepreneurs to negotiate remediation and compensation criteria differently in each case. In contrast to the process of reparation in Mariana-MG, the population of Brumadinho-MG is finding a policy of reparation of the right to housing while the only housing-related actions are described, in a report by Vale S.A. itself, as support for purchase and investment of residential and commercial real estate (Vale S.A., 2019). The difference in reparation criteria adopted reinforces the need for policies and general parameters for the reparation of the right to housing of dam-affected populations.

More tools to analyze the current situation should be developed as a way to help restore families affected by dams.

4. Findings and Discussion

With the disruption of the Fundão Dam, several rural properties have been affected and families must be resettled or compensated for this damage. We have found that most of the farms affected (65.7%) in the Gualaxo do Norte River basin - which was the first basin to be affected by the disaster - are micro-size farms (farms under 20 ha). This is a worrying fact since

properties with less than one module are not considered uneconomically viable.

The companies have financial compensation proposals, but the population wants the land to continue their activities. The recommendations and settlements agreements say that this population needs to be resettled under conditions equal to or better than the previous ones. Leaders of rural communities claim compensation by adding a Fiscal Module to the destination area. It is reasonable that each Family Resettlement should receive at least the addition of one Fiscal Module to their refund as the new property will be economically viable for its effective resumption of lifestyles.

In addition, agreements made and translated into "Housing Right Redress Guidelines" should be adequately implemented, and the approval of a National Policy on the Rights of Dam-Affected Populations is a matter of priority and urgent, as reports from public prosecutor and Mariana affected institutions show or point to gaps in the process of reparation or resettlement. Its approval will contribute to the reparation of the affected populations in Mariana and in future similar cases.

This work is an approach to a complex theme such as the repair of the populations affected by the disaster. We suggest that new works contribute to improve the accuracy of the measures necessary to repair the right to housing. Repair parameters and mechanisms for defining the area to be occupied in resettlements are examples of knowledge gaps in this area.

Acknowledgements

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

References

Aleixo, L. & Bastos, S. P. (2018) Perspectivas de Reparação no Caso Samarco: indivisibilidade, interdependência e direitos econômicos, sociais, culturais e ambientais. *Revista do Instituto Brasileiro de Direitos Humanos*, 17/18(1): 157-173.

Banco Mundial. (2003) *Grandes minas y la comunidad: efectos socioeconômicos en Latinoamerica,Canadá y España. Banco Mundial/Centro Internacional de Investigacione s para el Desarrollo*. Centro Internacional de Investigaciones para el Desarrolo, Ottawa, Cana da.

Barbosa, F. A. R, Barbosa, P.M.M, Nascimento, A.M.A, Rietzler, A.C. Franco, M. W, Paes, T. A, Reis, M. Moura, K. A.F. Dias, M.F, Ávila, M. P. & Oliveira, L.A.G. (2015) *O desastre de Mariana e suas consequências sociais, econômicas, políticas e ambientais: porque evoluir da abordagem de Gestão dos recursos naturais para Governança dos recursos naturais?* In: UFMG (Org.) Arquivos do Museu de História Natural e Jardim Botânico; Belo Horizonte.

Bermann, C. (2003) *Energia no Brasil: para quê? Para quem?* São Paulo: Editora Livraria da Física.

Brasil. IBAMA - Instituto Brasileiro do Meio Ambiente e Recursos Naturais Renováveis. (20015) *Laudo técnico preliminar. Impactos sociais decorrentes do desastre envolvendo o rompimento da barragem de Fundão, em Mariana, Minas Gerais*, Brasília: IBAMA, DIPRO, CGEMA. 38pp. Available in: <https://www.ibama.gov.br/phocadownload/barragemdefundao/laudos/laudo_tecnico_preliminar_Ibama.pdf > Acess in: April 21, 2019.

Brasil. INCRA - Instituto Nacional de Colonização e Reforma Agrária. (2008) *O que é módulo fiscal*. Available: <http://www.incra.gov.br/o-que-e-modulo-fiscal> Acess in: May 13, 2019.

Brasil. INCRA - Instituto Nacional de Colonização e Reforma Agrária. (2013) *Sistema nacional de cadastro rural - índices básicos de 2013*. Available in: <http://www.incra.gov.br/sites/default/files/uploads/estrutura-fundiaria/regularizacao-fundiaria/indices-cadastrais/indices_basicos_2013_por_municipio.pdf> Acess in: April 22, 2019.

Brasil. (1993) *Lei nº 8.629, de 25 de fevereiro de 1993. Dispõe sobre a regulamentação dos dispositivos constitucionais relativos à reforma agrária, previstos no Capítulo III, Título VII, da Constituição Federal.* Available in:<http://www.planalto.gov.br/CCIVIL_03/LEIS/L8629.htm> Acess in: April 22, 2019.

Brasil. Câmara dos Deputados. (2019) *Projeto de Lei PL 2.788/2019 Institui a Política Nacional de Direitos das Populações Atingidas por Barragens (PNAB); discrimina os direitos das Populações Atingidas por Barragens (PAB); prevê o Programa de Direitos das Populações Atingidas por Barragens (PDPAB); estabelece regras de responsabilidade social do*

*empreendedor; revoga dispositivos da Consolidação das Leis do Trabalho (CLT), aprovada pelo Decreto-Lei nº 5.452, de 1º de maio de 1943; e dá outras providências***.** Available in:< https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra;jsessionid=4260F03031044D7AE882615FB49EDBCD.proposicoesWebExterno1?codteor=1744723&filename=PL+2788/2019> Acess in: September 05, 2019.

Brasil. Ministério Público de Minas Gerais. (2019) *Ata de reunião (PA 0400.18.000003-8) – GT Interdisciplinar de Moradia do dia 24 de abril de 2019.* Mariana-MG.

Cáritas Brasileira. (2017) *Relatório Geral Reassentamento e Reconstrução, Agosto 2017*. Mariana-MG.

Costa, A. T. (2001) *Geoquímica das águas e dos sedimentos da bacia do Rio Gualaxo do Norte, leste-sudeste do Quadrilátero Ferrífero (MG): estudo de uma área afetada por atividades de extração mineral*. Ouro Preto: DEGEO/EM/UFOP. 146 pp. Dissertação (Mestrado em Evolução Crustal e Recursos Naturais. Área de concentração: Geodinâmica Superficial/Geoquímica Ambiental) - Programa de Pós-Graduação em Evolução Crustal e Recursos Naturais, Universidade Federal de Ouro Preto, Ouro Preto, 2001. Available in: <http://www.repositorio.ufop.br/handle/123456789/3242>. Acess in: May 05, 2019.

Coelho, R. M. P. (2015) *Existe governança das águas no Brasil? Estudo de caso: O rompimento da Barragem de Fundão, Mariana (MG)*; In: UFMG (Org.) Arquivos do Museu de História Natural e Jardim Botânico; Belo Horizonte.

Cruz, G. S. & Domingues, A. L. (2017) *Áreas impactadas na sub-bacia do Rio Gualaxo do Norte: rompimento da Barragem de Fundão, MG*. Disciplinarum Scientia. Série: Naturais e Tecnológicas, Santa Maria.

Derrosso, G. S. & Ichikawa, E. Y. (2014) *A construção de uma usina hidrelétrica e a reconfiguração das identidades dos ribeirinhos: um estudo em Salto Caxias, Paraná TT - The construction of a hydroelectric power station and the reconfiguration of the identities of riverside dwellers: the case of Salto Caxias, Paraná*. Ambiente & Sociedade, v. 17, n. 3, pp. 97–114.

Dos Reis, D. A., Fongaro, G., Da Silva Lanna, M. C., Dias, L. C. P., & Santiago, A. da F. (2019). *The Relationship Between Human Adenovirus and Metals and Semimetals in the Waters of the Rio Doce, Brazil*. Archives of Environmental Contamination and Toxicology. (2019) 77: 144. https://doi.org/10.1007/s00244-019-00625-w

EMATER - MG - Empresa De Assistência Técnica e Extensão Rural Do Estado De Minas Gerais. (2016) *Produtores rurais têm prejuízo de R$ 23,2 milhões com rompimento de barragem em Mariana*. Belo Horizonte: EMATER-MG, 16 Fevereiro 2016.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. (2012) *Sobre a Lei 12.651/2012*. Disponível em: <https://www.embrapa.br/codigo-florestal/area-de-reserva-legal-arl/modulo-fiscal> Acess in: May 10, 2019.

Fernandes, G. W. et al. (2016) *Deep into the mud: ecological and socio-economic impacts of the dam breach in Mariana, Brazil*. Natureza e Conservacao, v. 14, n. 2, p. 35–45, 2016. Disponível em: <http://dx.doi.org/10.1016/j.ncon.2016.10.003>.

Freitas, C. M., Silva, M. A. & Menezes, F. C. (2016) *O desastre na barragem de mineração da Samarco: fratura exposta dos limites do Brasil na redução de risco de desastres.* Cienc. Cult., São Paulo, v. 68, n. 3, p. 25-30, Setembro. 2016. Available in:<http://cienciaecultura.bvs.br/scielo.php?script=sci_arttext&pid=S0009-67252016000300010> Acess in: May 16, 2019.

Greenough, P.R. & Weaver, A.D. (1997) *Lameness in cattle*. 3. ed. Philadelphia: W.B.Saunders, 1997.

Instituto Brasileiro de Geografia e Estatística (IBGE). (2010) Cidades. Mariana - MG. Disponível em: <https://cidades.ibge.gov.br/brasil/mg/mariana/panorama> Acess in: May 18, 2019.

IFC (*International Finance Corporation*). (2012) *Guidance Note 5: Land Acquisition and Involuntary Resettlement*. Washington, DC.

IFC (*International Finance Corporation*). (2012) *Performance Standard 5: Land Acquisition and Involuntary Resettlement*. Washington, DC.

Landau, E. C., Cruz, R. K., Hirsch, A., Pimenta, F. M. & Guimarães, D. P. (2012) *Variação geográfica do tamanho dos módulos fiscais no Brasil*. Sete Lagoas: Embrapa Milho e Sorgo, Documentos nº 146, 2012.

Moreira, P. F. & Aly, O. J. (2018) *Agricultura familiar como sujeitos da agenda ambiental: Um olhar sobre o território atingido pela barragem de Fundão*. Available in:<https://www.uniara.com.br/legado/nupedor/nupedor_2018/5/10_Pedro_Moreira.pdf> Acess in: April 10, 2019.

Ramboll. (2017) *Avaliação do Programa de Reparação Integral da Bacia do Rio Doce*. Available in: <http://www.mpf.mp.br/para-o-cidadao/caso-mariana/documentos/relatorio-ramboll> Acess in: May 10, 2019.

Randell, H. (2016). *Structure and Agency in Development-Induced Forced Migration: the case of Brazil's Belo Monte Dam*. Population and Environment, 37,pp 265-287.

Rodrigues, A. S. L. (2012) *Caracterização da bacia do Rio Gualaxo do Norte, MG, Brasil: Avaliação geoquímica ambiental e proposição de valores de background***.** Tese (Doutorado) – Universidade Federal de Ouro Preto. Escola de Minas. Departamento de Geologia. Programa de Pós-Graduação em Evolução Crustal e Recursos Naturais; 2012.

Santamarina, J., Torres-Cruz, L. & Bachus, R. (2019) *Why coal ash and tailings dam disasters occur*. Science. Vol. 364, Issue 6440, pp. 526-528, May 2019.

Santos, J. P. dos, Cota, G. E. M.; Limoeiro, B. F.; Pedras, K. C.; Costa, A. M. da. & Viana, J. H. M. (2017) *Susceptibilidade à erosão no Rio Gualaxo do Norte-MG*. Caminhos da Geografia; 2017.

Shearer, J.K., Bray, D.R., Umphrey, J.E. et al. (1996) *Factors influencing the incidence of lameness in dairy cattle*. In: Annual Florida Dairy Production Conference, 33., 1996. Gainesville: Proceedings. Gainesville: UF.

Souza, R.C. (2002) *Perfil epidemiológico e clínico das afecções podais em vacas nas bacias leiteiras de Belo Horizonte e Pedro Leopoldo*. 2002. 72f. Dissertação (Mestrado) - Escola de Veterinária, Universidade Federal de Minas Gerais, Belo Horizonte.

Stanek, C. (1997) *Housing and nutrition related claw diseases of dairy cattle*. Israel J. Vet. Med. v.52, pp.80-87, 1997.

TJMG. (2018) *Ação Civil Pública: MPMG vs. Samarco S/A, Vale S/A e BHP Billiton Ltda. Processo n° 0400.154335-6*, 2a Vara da Comarca de Mariana.

Vale S. A. (2019) *Balanço da Reparação, setembro 2019***.** Brasil, September. Available in: <https://www.vale.com/brasil/PT/aboutvale/servicos-para-comunidade/minas gerais/atualizacoes_brumadinho/Paginas/Acoes-da-Vale-em-Brumadinho.aspx> Acess in: September 17, 2019.

Viana, J. P. (2017) *As atividades de pesca e aquicultura na Bacia do Rio Doce: subsídios para a mitigação dos impactos socioeconômicos do desastre da Samarco em Mariana, Minas Gerais***.** Boletim Regional, Urbano e Ambiental. Brasília: IPEA. pp.103-113. 2017.

Vormittag, E. M. P. A. De A., Oliveira, M. A. & Gleriano, J. S. (2018) *Avaliação de Saúde da População de Barra Longa afetada.* v. 21, 2018.

Zhouri, A. et al. (2016) *O desastre da Samarco e a política das afetações: classificações e ações que produzem o sofrimento social*. Cienc. Cult**.**, São Paulo, v.68, n.3, pp.36-40, Setembro 2016.

Zhouri, A., & Oliveira, R. (2007). *Desenvolvimento, conflitos sociais e violência no Brasil rural: o caso das usinas hidroelétricas.* Ambiente & Sociedade, 10(2), pp.119-135

Porcentagem de contribuição de cada autor no manuscrito

Juliano Scarpelin – 50%

Lário Moisés Luís Herculano – 25%

Lívia Cristina Pinto Dias – 15%

Vitorino Fernando Chume – 10%