ABECO
ASSOCIAÇÃO BRASILEIRA DE CIÊNCIA ECOLÓGICA E CONSERVAÇÃO

Natureza & Conservação
Brazilian Journal of Nature Conservation
Supported by Boticário Group Foundation for Nature Protection
http://www.naturezaeconservacao.com.br

Policy Forums

Neglect of ecosystems services by mining, and the worst environmental disaster in Brazil

Ana Carolina de Oliveira Neves[a,*], *Flávia Peres Nunes*[a], *Felipe Alencar de Carvalho*[a], *Geraldo Wilson Fernandes*[a,b]

[a] *Evolutionary Ecology & Biodiversity, Department of General Biology, Institute of Biological Sciences, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil*
[b] *Department of Biology, Stanford University, Stanford, United States*

ARTICLE INFO

Article history:
Received 24 January 2016
Accepted 11 March 2016
Available online 26 March 2016

Introduction

On 5 November, 2015, Brazil watched one of the worst environmental disasters in its history unfold. A wave of mud buried Bento Rodrigues, a village in the municipality of Mariana, located in the Espinhaço Mountains in the state of Minas Gerais (Escobar, 2015). Sixty-two million m^3 of sludge overwhelmed houses and the historical, cultural and natural heritage of the village, leaving 19 dead, 3 missing and over 600 homeless. On its way to the Atlantic Ocean, the wave of mud reached the Rio Doce (literally "Fresh" or "Sweet River") – a major drainage of the Southeastern Atlantic hydrogeographic region, which provides key ecosystem services to part of the country's most populous and industrialized region. It is also one of the main rivers to supply water and nourishment to the endangered Atlantic Forest. The disaster instantaneously caused the turbidity of the Rio Doce to reach a level 12,000 times higher than that allowed for consumption, and the oxygen level to suddenly drop below 1 mg/L (IGAM 2015), causing the death of several tons of fish and many other living organisms. Forty-one municipalities in the states of Minas Gerais and Espírito Santo were affected by the disaster and hundreds of thousands of people were left without access to clean water. The harm done to biodiversity has yet to be precisely estimated, but various institutes and scientists decreed the death of the Rio Doce along its ~600 km. The mud reached the Atlantic Ocean on 22 November, expanding the impacts to the fragile, yet diverse estuarine and coastal region.

The mudflow was caused by the failure of the Fundão iron-ore tailings dam owned by the mining company Samarco, a joint venture between BHP Billiton and Vale (Fig. 1). To make matters worse, Samarco has admitted that two more dams in the same mining complex where the tragedy struck are at

* *Corresponding author*.
E-mail addresses: ananeves@gmail.com (A.C.d.O. Neves), flaviaperesnunes@yahoo.com.br (F.P. Nunes), sig.leebufmg@gmail.com (F.A. de Carvalho), gw.fernandes@gmail.com (G.W. Fernandes).
http://dx.doi.org/10.1016/j.ncon.2016.03.002

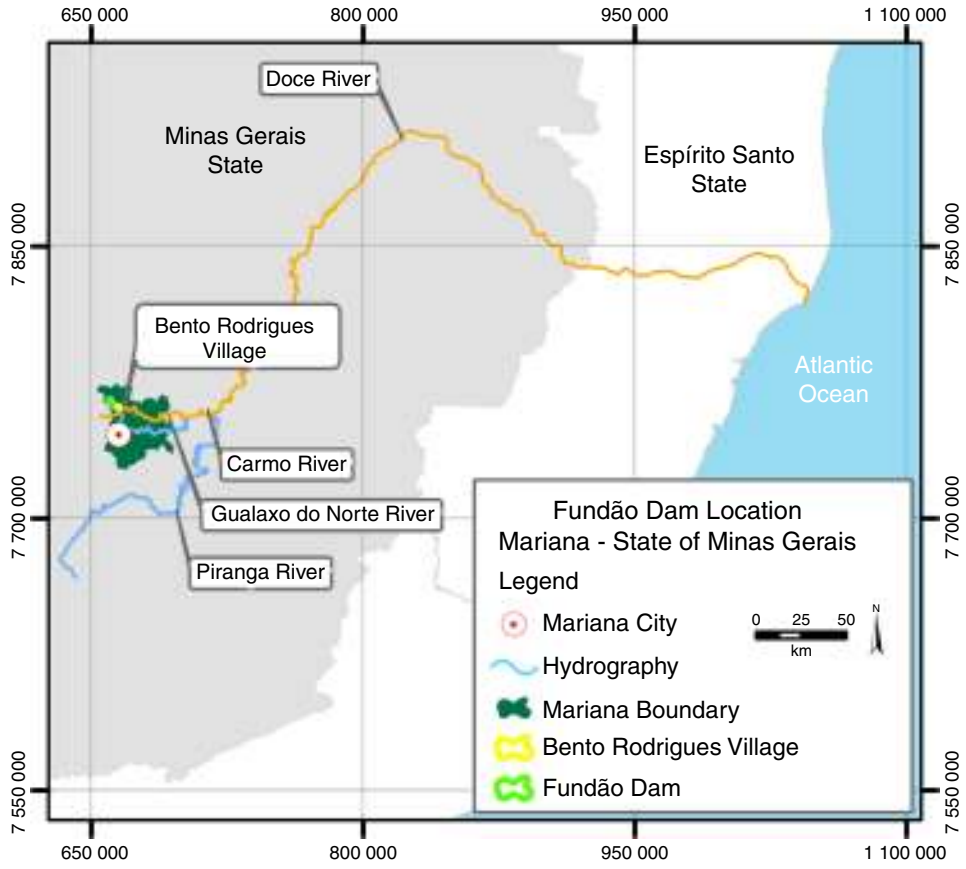

Fig. 1 – The Fundão iron-ore tailings dam location and the extension of the environmental damage caused by the dam break.

threat to collapse, as they present levels of stability of only 37% and 22%, while Brazilian standards recommend above 50% (O Globo, 2015). This is at least the seventh tragedy resulting from the failure of tailings dams in Minas Gerais in less than 30 years. Actually, forty-two out of the 735 dams in operation in the State have no guarantee of stability (FEAM, 2014).

Conflicts between mining and ecosystem services and goods

Mining involves important trade-offs between industry and ecosystem services/biodiversity conservation, because it converts multifunctional landscapes, that provide a myriad of ecosystem services, into monofunctional, mineral-provisioning landscapes (Neves et al., 2016). Some of the most affected ecosystem services by mining are those related to freshwater, such as water provisioning for agriculture, households and to support traditional livelihoods, water filtration, groundwater recharge, control of erosion and flood, and cultural services (Carpenter et al., 2009; McIntyre et al., 2014). The delivery of these services are generally compromised by direct water consumption by mining and pipelines, pollution of surface/groundwater, decrease of groundwater level and flow, and occasionally by environmental disasters such as the breaking of tailing dams and pipelines (Li et al., 2011; Neves et al., 2016). Also, mining deeply alters landscapes and destroys landmarks with geographical, historical or identity value, compromising the delivery of cultural services such as tourism, recreation and existence values (Neves et al., 2016). Notwithstanding the private and short-term benefits, the damage to ecosystems by mining has been harmful to society. In a simple cost-benefit analysis the disadvantages of such landscape conversion is not crystal-clear, as the cost of lost ecosystem services is not internalized, private/short term gain is prioritized over public/long term needs, and the cost-benefit ratio is distorted by tax or governmental incentives (MEA, 2005). Research on the valuation of ecosystem services has been trying to make the positive externalities offered by natural ecosystems visible by assigning them a monetary value (TEEB, 2010). However, these values were not assessed in determining the environmental fines for the disaster of Mariana and Rio Doce. The federal and State environmental authorities (IBAMA and SEMAD) imposed the maximum fines allowed by Brazilian law, while the Federal and Minas Gerais Public Prosecution Service made an extra-judicial agreement with Samarco regarding the recovery of damages. Obviously, the total amount of these fines, US$349.2 million (current dollar exchange rate of US$1 = R$3.90), does not equate with the value of ecosystem services and biodiversity lost, and is not even sufficient to recover the degraded area of the Rio Doce. For a comparison, the oil company BP was charged more than US$40 billion in fines and other payments for causing a massive oil spill in the Gulf of Mexico off the coast of the United States in 2010 (Wikipedia, 2016).

Recommendations

Given the current scenario, exacerbated by recent events, we propose eight measures to balance the trade-offs between mining and environmental preservation.

1. Investment in more rigorous licensing and permitting by government agencies. To accomplish this measure, environmental agencies need to increase their budget, staff, training and testing of the qualification of personnel. In addition, stricter criteria should be adopted for the licensing of mining enterprises. For example, the most popular design worldwide for enlarging the capacity to store tailings is upstream raised embankment. It is also the most commonly failing design, causing huge environmental damage all over the world (ICOLD & UNEP, 2001), including the Samarco dam in Mariana. In 2013, Samarco had its operating license for Fundão dam renewed by the environmental agencies, despite opposition of the Minas Gerais Public Prosecution Service based on a technical report. Despite such recommendation, only a few days after the disaster in Mariana, the project law PL 2946/2015 were approved by the Legislative Assembly of Minas Gerais and PL 654/2015 is ready for Brazilian Senate decision, under the justification of accelerating the licensing process for ventures. Actually, both proposals do not act on the real causes of inefficiency, but recklessly limit the participation of civil society in the licensing process (local communities, non-governmental organizations, the Public Prosecution Service, etc.).
2. Protection of reference ecosystems that are rich in minerals, as many of them are also extremely biodiversity-rich (as is the case with the Brazilian rupestrian grasslands in the Espinhaço Mountain Range; Neves et al., 2016). Current Brazilian law requires companies to create of protected areas in the same river basin as compensation for environmental damages, but it does not require protection of the same ecosystems as those affected by their enterprises. The result has been the poor representation of ironstone *rupestrian grasslands* among the national network of protected areas, since they are the most mineral rich ecosystem (Jacobi and Carmo, 2008). Also, mining companies must invest heavily in the development of the knowledge, methods and techniques needed to restore landscapes and degraded rivers adjacent to mining areas.
3. Investment in economic activities that use the multifunctionality of landscapes, taking advantage of the many ecosystem services available, and granting society as a whole their right to profit from their long-term preservation. This strategy has the potential to reduce the cost of water purification, and the avoidance of environmental disasters, such as landslides, by maintaining native vegetation, among other benefits. This could also generate profit through tourism, provision of raw materials or on the carbon market, just to cite a few examples.
4. Use of ex-ante planning for territory management. Prior to undertaking large ventures such as mining, local and regional planning should be undertaken in an attempt to anticipate impacts and interventions in the territory including the integration of relevant players, in order to create positive synergies between mining and social, economical, cultural and environmental sectors. This strategy could contribute to the correction of power asymmetries among agents, guarantee the rights of vulnerable social groups (such as indigenous, traditional or local communities), define a network of public and private protected areas, and facilitate urban planning for the receipt of imigrants (Barbieri et al., 2014).
5. Internalize environmental services in cost-benefit analysis of enterprises, and incorporate the cost of their loss in the calculation of fines, using environmental valuation techniques. To attain such recommendation, the government could foster the valuation and monitoring of ecosystem services lost by mining operation countrywide. Some tools that could speed up the process are the availability of databases, the establishment of protocols and the setting of local and regional reference values.
6. Improve the tax rate on mining products. Mining companies financially compensate the government for the extraction of natural resources by means of "mining royalties". In Brazil, the correspondent tax ("Compensation for the Exploitation of Mineral Resources", CFEM) is indexed *ad valorem*, i.e. on net invoicing obtained from product sales, and corresponds to only 2.0% for iron (IBRAM, 2012). Such amount is smaller than in countries such as South Africa (0.5–7.0%; PWC, 2012) and Bolivarian Republic of Venezuela (3%; Otto et al., 2006), especially when one considers that the exploitation of iron in Brazil is much cheaper (Santos, 2012). To establish the proper compensation for the conversion and degradation of ecosystems, a more realistic counterpart value for the exploitation of mineral goods in Brazil should be defined. The Regulatory Framework for Mining, a project law (PL 5.807/2013) that is under discussion in the Brazilian Congress, proposes, among other changes, an amendment changing how CFEM is calculated, increasing the maximum rate from 3% to 4%.
7. Invest mining royalties in the preservation of nature. Protected areas receive inadequate financial benefits from the mining industry for their use of land and water, as there are no mandatory criteria for the investment of mining royalties into the conservation of nature in Brazil. It would be beneficial for municipalities to team up with the mining sector and invest the royalties into promoting 'green municipalities' and to cover the cost of maintaining and restoring damaged ecosystems (Domingues et al., 2012).
8. Diversify production matrixes based on commodities. The Brazilian economy is mainly focused in the primary industry. For example, in October 2015, Brazil exported 341.5 million tons of iron ore at US$ 33.2/ton and only 7.09 million tons of semi-manufactured iron and steel priced at US$ 309.3/ton (MDIC, 2015). The trade balance of the sectors with steel as the main raw material (vehicles, machinery, equipment, etc.) is deficient. The country would greatly benefit from investing in innovation and technology so that goods with higher added value could be exported, instead of prioritizing commodities.

Beyond such recommendations, a path toward long-term sustainable socio-economic and environmental development requires a critical analysis of the hegemonic model of

development through unlimited economic growth, followed by a deep shift in paradigms (Daly and Farley, 2004). Such a change implies, for example, reducing society's consumption levels. While society still resists that alternative, we must take urgent measures to contribute to the reduction of mining impacts or, at least, to better compensate society and the environment for mineral exploitation.

Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

Barbieri, A.F., Domingues, E.P., Monte-Mór, R.L.M., Santos, F.B.T., Rigotti, J.I.R., Rodrigues, B.H.M., Tonucci, J., Neto, O.B., Cortezzi, F., 2014. Plano regional estratégico em torno de grandes projetos minerários no médio Espinhaço. FUNDEP, Belo Horizonte.

Carpenter, S.R., et al., 2009. Science for managing ecosystem services: beyond the Millennium Ecosystem Assessment. Proc. Natl. Acad. Sci. U. S. A. 106, 1305–1312.

Daly, H.E., Farley, J., 2004. Ecological Economics: Principles and Applications. Island Press, Washington.

Domingues, S.A., Karez, C.S., Biondini, I.V.F., Andrade, M.A., Fernandes, G.W., 2012. Economic environmental management tools in the Serra do Espinhaço biosphere reserve. J. Sustain. Dev. 5, 180–191.

Escobar, H., 2015. Mud tsunami wreaks ecological havoc in Brazil. Science 350, 1138–1139.

FEAM, 2014. Inventário de barragem do Estado de Minas Gerais. Fundação Estadual do Meio Ambiente, Belo Horizonte.

IBRAM, 2012. Informações e análises da economia mineral Brasileira. Instituto Brasileiro de Mineração, Brasília, http://www.ibram.org.br/sites/1300/1382/00002806.pdf.

ICOLD, UNEP, 2001. Tailings Dams – Risk of Dangerous Occurrences, Lessons Learnt From Practical Experiences (Bulletin 121). Commission Internationale des Grands Barrages, Paris.

Jacobi, C.M., Carmo, F.F., 2008. The contribution of ironstone outcrops to plant diversity in the Iron Quadrangle, a threatened Brazilian landscape. Ambio 37, 324–326.

Li, F., Liu, X., Zhao, D., Wang, B., Jin, J., Hu, D., 2011. Evaluating and modeling ecosystem service loss of coal mining: a case study of Mentougou district of Beijing, China. Ecol. Complex. 8, 139–143.

McIntyre, N., Bustamante, N., Hauck, E., Manz, B., de Bievre, B., (action research report) 2014. Mining and River Ecosystem Services. International Mining for Development Centre, Perth.

MDIC, 2015. Ministry of Development, Industry and Foreign Trade, http://www.mdic.gov.br/sitio/interna/interna.php?area=5&menu=1955&refr=608.

MEA, 2005. Ecosystems and Human Well-Being: Biodiversity Synthesis. World Resources Institute, Washington.

Neves, A.C.O., Barbieri, A.F., Pacheco, A.A., Resende, F., Braga, R.F., Azevedo, A.A., Fernandes, G.W., 2016. The human dimension in the Espinhaço Mountains: land conversion and ecosystem services. In: Fernandes, G.W. (Ed.), Ecology and Conservation of Mountaintop Grasslands in Brazil. Springer International Publishing AG Switzerland, Cham, pp. 501–530.

O Globo. Available from http://oglobo.globo.com/brasil/samarco-admite-risco-de-rompimento-em-mais-duas-das-barragens-18072191 (accessed March 2016).

Otto, J., Andrews, C., Cawood, F., Doggett, M., Guj, P., Stermole, F., Stermole, J., Tilton, J., 2006. Mining Royalties – A Global Study of Their Impact on Investors, Government, and Civil Society. The International Bank for Reconstruction and Development/The World Bank, Washington.

PWC, 2012. Corporate income taxes, mining royalties and other mining taxes – a summary of rates and rules in selected countries, https://www.pwc.com/gx/en/energy-utilities-mining/publications/pdf/pwc-gx-miining-taxes-and-royalties.pdf.

Santos, R.S.P., 2012. Fundamentos para a criação de um fundo social e comunitário da mineração no Brasil Cadernos do Observatório do Pré-Sal e da Indústria Extrativa Mineral., http://dx.doi.org/10.13140/RG.2.1.2076.8806.

TEEB, 2010. The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB.

Wikipedia. Available from https://en.wikipedia.org/wiki/Deepwater_Horizon_oil_spill (acessed March 2016).