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Policy Forums

Degradation by coal mining should be priority in restoration planning

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ABSTRACT

In the southern part of the Atlantic Forest region, in Santa Catarina, Brazil, coal mining has led to severe degradation, with former mining areas abandoned decades ago without any concern about environmental and social damage. Up to recently, little restoration activity had been developed, despite severe and ongoing environmental degradation that also causes risks to human health. We argue that these areas should be made restoration priority, and that the development of specific restoration actions and measures for sites like these are urgent. To achieve effective restoration planning we must overcome some challenges, such as prioritization of areas for restoration, establishment long-term monitoring, development of realistic goals, avoidance of the use of invasive grasses, and inclusion of human population and their needs into discussion of restoration goals and approached. We recognize that, due to pollution and contamination problems, cost for restoration is a massive challenge in the region, but even higher costs for population and environment are expected if sites would not be restored. Considering the environment and human health risks of areas degraded by coal mining, restoration efforts should be of high priority on all level of governance, and ways should be found to include this into the procedures for prioritization of restoration activities.

Introduction

Priority setting is essential in large-scale restoration programs. This is especially true in large and diverse regions, such as Brazil's Atlantic forest that includes a variety of landscape conditions and different types of degradation (Ribeiro et al., 2009; Rodrigues et al., 2011). Landscape connectivity and ecosystem resilience have been considered important features for the definition of priority areas for restoration (Stefanes et al., 2016). Once priorities have been established, restoration activities usually focus on tree species diversity, and they may include both passive restoration and many types of active interventions (Chazdon, 2008; Holl and Aide, 2011; Omeja et al., 2011; Rodrigues et al., 2011).

Such initiatives – with many examples for application (e.g. Liu et al., 2017; Rodrigues et al., 2011) – are of high importance to reach national and global restoration goals, such as those proposed in the Brazilian PLANAVEG (MMA, 2015). However, little focus is placed on specific challenges with a smaller spatial extent, such as areas degraded by mining, both in terms of priority setting and in development of restoration techniques. It is true that they only constitute a minor percentage of total area to be restored in the Atlantic forest, but they represent an immense risk for environment and human health (Milioli, 2005; Zooche et al., 2010).

Here, we present the case of southern Santa Catarina, Brazil, a region where considerable areas (some 6500 ha) were abandoned after coal mining, without any concern about environmental and social damage (Milioli, 2005; Rocha-Nicoleite et al., 2013; Rocha-Nicoleite, 2015). While mining of some areas was halted decades ago, restoration activities were only started late, despite severe degradation and still ongoing environmental pollution, and are clearly not sufficient. We argue that these areas should be made restoration priority, and that development of restoration actions designed to tackle the specific problems in the region as well as adequate monitoring are urgent. On sites where coal mining still is taking place (six mines that together produce about 550,000 tons of coal per month, about one third of previous production; ABCM, 2017), with still some consequences for the environment,

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Fig. 1. Degradation caused by coal mining. On the picture, spoils from mining that had been deposited at the bank river of the Rio Bonito in Lauro Müller municipality, southern Santa Catarina, Brazil. This area can be considered degraded throughout the past 70 years, and no change of this is at sight.

restoration planning today is included into project planning following current environmental laws. However, even though environmental concerns have increased and mining approaches and techniques have changed, it seems reasonable that available experiences with restoration are still too scarce for effective restoration of ecosystem biodiversity and functioning (Macdonald et al., 2015).

Areas degraded by coal mining: environmental problems make them priority

In southern Santa Catarina state, Brazil, coal mining mostly took place from 1940 to 2000 (Citadini-Zanette, 1999). These activities resulted in a total of 6500 ha of severe degraded land in three watersheds (Araranguá River, Urussanga River and Tubarão River) (Brasil, 2015). Degradation conditions vary between sites but in general mean strong contamination of both physical (water and soil) and biological (fauna and flora) components of the ecosystems (Campos et al., 2003; Santos et al., 2008; Silva et al., 2013). Riparian zones are especially vulnerable areas. Here, besides severe local effects (Rocha-Nicoleite et al., 2013; Rocha-Nicoleite, 2015), degradation may have far-reaching consequences due to flowing water that may pollute further downstream sites (Fig. 1). Spoils from mining often had been deposited at riverbanks, which led to the destruction of riparian forests and to long-lasting high levels of heavy metals in water. In some rivers the pH reaches 3.0 (see water monitoring, Brasil, 2013). High-sulphur coals, as those found in Santa Catarina (Chaves, 2008), contain high concentrations of pyritic sulphur that may produce Acid Mine Drainage (AMD), which can be considered the most dangerous long-term problem associated to coal mining (Silva et al., 2011). AMD causes contamination of soil and water and inhibits the development of many organisms principally due to the low pH (Zooche et al., 2010). These environmental conditions also pose concrete risks for human health either due to the run-off of heavy metals contaminants to nearby occupied sites or due to direct human use of the areas, e.g. for livestock or human housing, even though anthropogenic use of these degraded sites is prohibited.

Current restoration initiatives: an important start

In 2000, the mining companies and the Federal Government were sentenced to reclaim this damage (Brasil, 2016). The Federal Government was considered co-responsible for the degradation and, in consequence now is responsible for the restoration in two situations: areas mined before 1972, due to the difficulty to define owners and culprits for the damage, and areas mined by companies that went out of business or bankrupted.

Throughout the following seven years, the first restoration projects were elaborated and implemented. Initially, restoration was understood as only planting native trees, as restoration aim was the establishment of vegetation cover. However, many problems arose because of non-effective reclamation actions. In 2008, a guideline document (in Portuguese: "Critérios técnicos para recuperação ou reabilitação de áreas degradadas pela mineração de carvão") was elaborated by the Federal Public Prosecutor office, specifically for this region, and became mandatory (Brasil, 2013). This document established that all contaminant materials must be removed from riparian zones, considering their designation as Permanent Protection Areas (Brasil, 2012) and their importance for protection of water resources and as habitat (Gregory et al., 1991). After removal of mining waste, the topography has to be rebuilt with an inert material. Then, topsoil has to be constructed and a riparian forest re-established. To avoid erosion processes of the newly constructed soil, the document also determines the necessity to quickly establish vegetation cover. Up to now this has been usually done through seeding exotic grasses, such as *Avena sativa* L. and *Lolium multiflorum* Lam. in winter, and *Urochloa* spp. in summer. The guideline document also established that in non-riparian zones, spoils do not need to be removed but must be sealed to avoid producing AMD. These non-riparian areas could then be under different kinds of land uses, as long as technically feasible and not risking environmental damage.

Considering all impacted areas of the studied area, restoration projects have been (or are to be) initiated on 3722 ha (~57% of total area). From those areas with some restoration activity, only 1141 ha are being monitored by help of indicators for water and soil quality and considering geotechnical and biotic conditions (Brasil, 2015). Forty-three percent remain so far with no actions implemented, despite the existence of a schedule for the recuperation of all areas (at current, this schedule is until 2029). At any rate, most of initiated projects are not concluded and many challenges remain.

Main challenges

To prevent damage or restore degraded land the first step is planning (Holl and Aide, 2011). As exposed above, the general guideline elaborated in 2008 established clear objectives for the reclamation of those post mining sites and some restoration initiatives have started. However, various aspects have not been solved yet. Here, we summarize the main challenges, many of them identified as important in guidelines of coal mining restoration around the world (Chamber of Mines of South Africa/Coaltech, 2007; Government of Saskatchewan, 2007; Nova Scotia Environment, 2009):

- *Effectively removing pollution and decontamination in watersheds must be priority*:
  Removing or sealing of contaminating materials are effective actions to control pollution and reduce AMD. By removing mine spoils and reconstructing the soil at upstream riparian sites, is possible to improve the watershed water quality already in the first years of restoration, allowing, for instance, the colonization by some fish species (Brasil, 2015). Thus, upstream-pollution sites should be priority in restoration to raise the restoration effectiveness of watersheds. At current, there are no criteria for prioritization and the schedule for sites restoration is being filled out based on pragmatic decisions, such as ownership questions and costs for restoration.

Fig. 2. Riparian forest in process of ecological restoration after coal mining in Lauro Müller municipality, watershed of Tubarão River. The restoration project was established in 2010 and this photo was taken six years later (2016).

- *Long-term monitoring is needed because of environmental risks associated to pollution; however, distinct targets should be established for different restoration phases*:

  At current, all areas under restoration must to be monitored at least for five years and the responsibility is of the same company (or the government) that must do restoration. After this time, an evaluation is made and if the indicators (considering water, soil, flora and fauna) are not at the levels required by law (see Brasil, 2013), the area is maintained under monitoring. Up to now, no area was considered "restored". At sites where restoration activities had started more than a decade ago, initial phases of a successional forest may be present (Fig. 2), but nonetheless, the groundwater does not present acceptable conditions. While this shows the complexity of restoration at these sites, it also means that the process may be very expensive in the long-term. Considering the various aspects of the ecosystem, including contamination risks, it is problematic to consider an area as restored after only a short period of five or ten years, as new contamination spots may arise, e.g. from flowing water. For post-mining areas in the North American Great Plains, for example, the mining companies are obliged to keep records on restoration activities for ~50 years, which also facilities adaptive management to achieve the desired target (Rinella et al., 2016). In the case of forest restoration, the time to achieve the structure of reference ecosystems can be very long (Rocha-Nicoleite, 2015). In post-mining restoration projects goals must be established according to different time spans of restoration, as already adopted in some provinces of Canada (Nova Scotia Environment, 2009; Government of Saskatchewan, 2007) and in South Africa (Chamber of Mines of South Africa/Coaltech, 2007). Thus, monitoring parameters should indicate the restoration pathway and potentially useful adaptive management approaches to achieve the targets (Block et al., 2001), irrespective of a fixed time, but based on outcomes (Chaves et al., 2015).
- *Necessity to establish realistic goals – is it feasible to establish the original plant community?*

  Considering the magnitude of disturbances caused by coal mining and the necessity to reconstruct topographic and soil conditions, besides contaminant control actions, the establishment of a forest community similar to pre-disturbance state may simply not be a realistic goal due to the low (or completely lacking) ecosystem resilience (Doley and Audet, 2015; Holl and Aide, 2011). Keeping up this goal will easily lead to frustration. While ecological standards still should be high, it nonetheless seems more reasonable to establish realistic targets and regulatory frameworks that acknowledge that variation in objectives and outcomes can facilitate the restoration process (Macdonald et al., 2015). Moreover, future land uses to be established in restored areas must also consider social aspects besides the environmental, inclusive for agriculture or recreation (Siminski et al., 2016).
- *Avoid use of invasive grasses*

  Exotic invasive species, especially grasses, exert strong competition for the establishment of woody species and increase the risk of failure of the restoration (Hui-na et al., 2014; Rocha-Nicoleite, 2015). We highlight the necessity to avoid the use of invasive species in forest restoration projects, such as many of the perennial grasses commonly used, because they can inhibit or severely alter the successional trajectory (Macdonald et al., 2015), apart from potentially degrading vegetation cover at nearby sites. Instead, native herbaceous species should be used for a first vegetation cover of unstable soils. A big problem is that at current only very few herbaceous native species are available on the Brazilian market for restoration (see also Overbeck et al., 2013).
- *Necessity to include population and their needs*

  Inclusion of local population into goal-setting and planning of restoration is important for acceptance and success of restoration projects in general (Burke and Mitchell, 2007). When landowners are not included in the restoration planning, successful is seriously compromised. In Santa Catarina's coal mining region, areas exist where, even after many years of restoration, vegetation development is continuously stopped by fire set by local people. We thus recommend the establishment of a wide dialog between local people and all stakeholders to define the restoration goals (Hobbs and Harris, 2001). This also includes that local people should be informed about the health and environment risks of the areas, as well as about restrictions and potential for use of these areas after restoration.
- *Costs – High costs of restoration, but even higher costs for population and environment if not restored!*

  The average cost for restoration (including monitoring for five years) of areas that are under responsibility of Federal Government in the Criciúma region is about US$ 80 thousand/ha, varying from US$ 30 thousand/ha to US$ 180 thousand/ha (Brasil, 2015). These are the costs for restoration actions themselves – which do not consider the "costs" for local population. These values lie considerably above those generally given for restoration of Atlantic Forest areas (for example, around US$ 4 thousand/ha including management in the first two years) (LERF/ESALQ, 2009).

  Costs for restoration of these heavily degraded sites are high, but if sites would not be restored, long-term costs may be even higher and impossible to evaluate in monetary terms. Natural conditions have been entirely lost, and local population and ecosystems are suffering with consequences of degradation by coal mining and all related risks to human health.

Conclusion

The environmental problems related to coal mining in southern Santa Catarina have been neglected for many years, and they are not sufficiently considered in the restoration debate in Brazil. Most people who live around these areas are used to the situation and consider coal mining an important economic activity for the region; risks to environment or even human health are dismissed. Considering the immense environment and human health risks of areas degraded by coal mining, restoration efforts should be of high priority on all level of governance, and there need to be ways to include this into the procedures for prioritization of restoration activities. When restoration of former coal mining areas is initiated, it is important to adapt restoration procedures to the specific site conditions and to keep goals realistic.

Conflicts of interest

The authors declare no conflicts of interest.

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