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Restoring Brazil's road margins could help the country offset its CO_2 emissions and comply with the Bonn and Paris Agreements

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ABSTRACT

Ambitious aims have been set for the ecological restoration of degraded land worldwide. The first step to reach this goal is to identify suitable areas for restoration. Here, we advocate for the restoration of roadsides, an often neglected landscape that is usually degraded. Using Brazil as an example, we calculate the potential of roadside restoration for carbon storage, and discuss other additional positive environmental impacts. We show that in Brazil more than 566 thousand hectares of roadsides along federal and state highways are potentially available for restoration. This corresponds to a sequestration of up to 55.3 million tons of carbon, representing up to US$ 26.5 billion in the carbon market. Additional benefits would include erosion control, prevention of landslides, increased landscape value, pollinator habitat provisioning, and contribution to biodiversity conservation. We push for roadside restoration for its many environmental benefits and other practical reasons: roadsides in Brazil are governmentally owned, reducing the needing for negotiations with stakeholders in proposed interventions. Roadside restoration, however, is unlikely to re-establish predisturbance ecosystem conditions in all cases, but it may significantly contribute to biodiversity conservation, for instance, by providing habitat and increasing ecological connectivity for specific taxa and biomes. Thus, the restoration of roadsides in Brazil represents an immense potential for carbon sequestration, with other important environmental benefits. Proper management is necessary, and concrete strategies and goals in restoration planning will vary among different Brazilian biomes. The restoration of these currently undervalued public lands can make the financial and environmental benefits of land restoration evident to stakeholders and thus stimulate ecological restoration.

Introduction

Facing dire perspectives of biodiversity collapse, loss of ecosystem services, and the threat of climate change, society is urging for sound strategies aiming at the long-term maintenance of the world's ecosystems. Lack of governance on environmental issues, increasing population consumerism, and unfolding impacts on the natural resources are leading to unpredictable volatile effects on food production, water resources, and population health throughout the world (Watson et al., 2000; Stocker et al., 2013; Novais et al., 2016; Ceballos et al., 2017). Led by international agencies (e.g., UN), many countries are now working on global agreements and strategies to mitigate and adapt to the challenges imposed by global change as a response to the aggravation of the environmental crisis (Mace, 2014; Nimmo et al., 2015; Szinwelski et al., 2015).

Commitments within such strategies are the Bonn Challenge (http://www.bonnchallenge.org), whose aims include the restoration of 150 million hectares of the world's deforested and degraded land by 2020, and the New York Declaration on Forests, endorsed at the 2014 Climate Summit, that aims to restore 350 million hectares by 2030. While these initiatives are welcome and very

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relevant, there has been a hot debate about where and how to run restoration initiatives (see Veldman et al., 2015a,b; Fernandes et al., 2016a). For instance, the recently proposed afforestation of grasslands and savannas can bring more problems than solutions in terms of carbon sequestration (e.g. Berthrong et al., 2012; see also Deng et al., 2017). The introduction of trees where they have not been present historically can have disastrous impacts on local biodiversity and associated ecosystem services (Fernandes, 2016). Thus, these effects must be considered as restoration involves much more than simply planting trees. Ultimately, we must define the identity of the ecosystem in question in order to restore it with native species and bring back its biodiversity and ecosystem services (e.g., Overbeck et al., 2015; Kollmann et al., 2016).

In this paper, we advocate for a well conducted and scientifically oriented restoration of roadsides. We define roadsides as the environment alongside paved roads, which in Brazil generally comprises 15 m on each side. These areas have been completely neglected as a target for restoration, despite their high potential. Roadsides occupy a considerable area but are often degraded, suffering from erosion, covered by invasive species, or even left in bare soil. In some cases, roadsides are illegally used for parking, house construction, and increasingly for food production. The latter can have different forms, depending on the socio-economic context of the region: they may be used for small-scale farming, often using slash and burn as the management strategy, or simply be incorporated into adjacent agricultural areas. The construction of paved roads and their management has many impacts on biodiversity and ecosystem services around the world, including wildlife kills, the spread of wildfires and invasive species, chemical and noise pollution, erosion, and watercourses siltation (see Ibisch et al., 2016 for a recent review). Even more importantly, roads are a major facilitator of (often uncontrolled) deforestation, especially in tropical countries (Laurance et al., 2009). In the Brazilian Amazon, for example, 94% of deforestation has occurred within 5.5 km of a road (Berber et al., 2014) and represents a great threat to biodiversity (Vale et al., 2008).

In many countries, road construction and maintenance lack the most basic concerns with conservation and impact mitigation. In Brazil, for instance, although there are many state and federal regulations to reduce the environmental impact of roads, there is practically no law enforcement by governmental agencies (Fernandes, 2016). This has led to an unsurprisingly high number of these same agencies allowing the use of noxious invasive species in the revegetation of disturbed roadsides (Hilário et al., 2011) (Fig. 1).

If scientifically guided and properly restored, these areas could dramatically increase carbon sequestration as well as provide other ecosystem services. These include control and prevention of erosion and landslides, reduction of noise and chemical pollution, containment of invasive species, and conservation and enhancement of native biodiversity – for instance, by providing habitat and by connecting natural ecosystems. To illustrate and provide empirical support to our proposal, we take a hypothetical scenario where all state and federal paved roads in Brazil would have their roadsides properly restored, i.e. according to the native vegetation the roads cross through. The Brazilian case is particularly interesting because the country has set a national commitment to restore 12 million hectares of land by 2030, as part of the Bonn Challenge and the Paris Agreement of the United Nations Framework Convention on Climate Change (Brazil iNDC, 2015). We argue that if roadsides were properly restored instead of being left degraded and unprotected, they could help Brazil meet its carbon sequestration commitment and restoration goals, while additionally contributing to the provisioning of ecosystem services and to the mitigation of a number of negative effects of roads on the environment.

Material and methods

We used the complex and large paved road system of Brazil, which comprises more than 210,000 km and spans six biomes. We focused on paved roads because they are known to be more environmentally harmful than unpaved roads (e.g. Nepstad et al., 2001), which generally have low traffic, with a lesser impact on roadsides and no intentional introduction of exotic species (Barbosa et al., 2010). Despite plans for expansion of the road network in Brazil and ongoing road maintenance work, this is currently the best scenario available to perform our calculations. We followed the Brazilian federal legislation on land allotment (Federal Law 6.766/1979), which determines that 15 m along each roadside should be set aside. Thus, we calculated the area within the 15 m on each side of paved roads from each biome. We excluded urban areas, which we assumed not to be available for restoration, even though very often the environmental damage done during construction can be considered here as well (e.g., Barbosa et al., 2010). Spatial data on paved roads were acquired from the Brazilian National Transport Infrastructure Department (DNIT, http://www.dnit.gov.br), biome data from the Brazilian Ministry of the Environment (MMA, http://www.mma.gov.br) and urban areas from the Brazilian Institute of Geography and Statistics (IBGE, http://www.ibge.gov.br).

We do acknowledge that there are some variables that could be estimated which would make our model more realistic. However, the main aim of this exercise is to provide the first insights into the potential for roadside restoration to enhance environmental quality and carbon sequestration in these areas. We are aware, for instance, that there might be practical or technical reasons why restoring to the immediate edge of the road may not be feasible everywhere. For example, tree roots could damage the pavement, while leaves and debris could prevent roads from efficiently draining during storms, or could fall on vehicles. Also, some locations will not be available for restoration due to intersections or other infrastructures, or because they have been illegally occupied. In addition, traffic signs or road signs erected at the side of roads must be visible to give instructions or provide information to road users. On the other hand, larger roads often contain median strips, usually with herbaceous or shrub vegetation that could also have some potential for restoration actions. In addition, there may be public land adjacent to the roadsides that would be available to be included in the planning. In virtually all road construction in Brazil, vegetation removal along roads is larger than the expected, patios are created for construction equipment, and sand, gravel, or slate are excavated from the ground and used in the road pavement. Here, however, we simplify and assume a scenario where roadsides could be restored throughout their entire width. Given the scale we are working at, it would be difficult to account for potential losses and gains in area, due to specific constraints, simply because data are not available in such a fine resolution for the whole country

To calculate the area of roadsides that can be restored inside each biome we used the package raster v2.5-8 (Hijmans and van Etten, 2012) implemented in R (R Development Core Team, 2010). We calculated the amount of carbon that can be sequestered by properly restored roadsides based on previous estimates made for the native vegetation of each of the six Brazilian biomes (see Milton et al., 2015). We used the estimated values of 150 t C ha^{-1} for forest environments for the Amazon and Atlantic Rain Forest biomes (Malhi and Grace, 2000; Amundson, 2001; Baker et al., 2004; Chave et al., 2008; Lewis et al., 2009), 50 t C ha^{-1} for savanna/grassland ecosystems as the Cerrado, Pampa, and Pantanal biomes (Watson et al., 2000; Grace et al., 2006; Ward et al., 2014), and 15 t C ha^{-1} for the xeric Caatinga biome (Amundson, 2001; Grace, 2004). In addition, although Brazil has not yet regulated its carbon market, we estimated the monetary value of carbon that could be traded, considering the unit values adopted by the main climate finance

Fig. 1. Brazilian roadsides along paved highways are the scenario of many environmental problems. (a) Area along MG-10 left alone for many years and later ill-restored with noxious weeds by the Department of Roads of the state of Minas Gerais (DER-MG). (b) Spread of ruderal and invasive species into pristine vegetation from highway MG-10. (c) "Restoration" of highway MG-735 roadside in Minas Gerais (DER-MG) with exotic African grasses and other species. (d) Use of roadside along highway GO-118 (Brasilia-Alto Paraíso) to expand the plantations of soybean and bean. (e) Plantation of corn to the very edge of the RS-472 in Rio Grande do Sul state. (f) Plantation of soybean and plantation/invasion of pine trees along BR 290 in the Pampa, Rio Grande do Sul state.

initiative in Brazil (the Amazon Fund), and the minimum and maximum carbon prices of existing initiatives in the world: US\$1/tCO_2e and US\$131/tCO_2e, respectively (World Bank et al., 2016). In this calculation, the C was converted to CO_2, since the biophysical value sequestered is in the first unit and the market value in the second unit. This transformation was performed using the ratio of molecular weights (44/12). We also calculated, based on estimates by Benini and Adeodato (2017), the restoration costs for each biome, using a currency exchange of 1 Brazilian Real to 0.30 US Dollars. As restoration costs vary depending on site conditions and restoration technique used, we used the minimum and maximum cost associated with natural regeneration under good environmental conditions and active restoration under poor environmental conditions, respectively: US\$54.00 to US\$5247.60 ha^{-1} for the Amazon, US\$55.50 to US\$6381.30 ha^{-1} for the Atlantic Forest, US\$54.00 to US\$6683.70 ha^{-1} for Cerrado, US\$54.30 to US\$5984.40 ha^{-1} for the Caatinga, US\$94.50 to US\$8547.60 ha^{-1} for Pantanal and US\$54.30 to US\$7755.00 ha^{-1} for the Pampa. In theory, we would have to subtract current costs of maintenance and management of roadside area from this value, but these data are not available. We are aware that our calculations are based on relatively coarse estimates regarding: (1) total area to be restored, (2) carbon sequestration potential, (3) carbon prices, and (4) restoration costs. On the other hand, the carbon estimates we use are most likely quite conservative. For example, for soil stocks, estimates exist for some regions that exceed the values we used (e.g. Paiva and Faria, 2007 for Cerrado; Tornquist et al., 2009 for Pampa). This should offset possible uncertainties in the other parameters used in the calculations, or limitations for restoration due to technical issues.

Results

The 30 m (15 m on each side) alongside federal and state paved highways in Brazil represent an area of ~585,600 ha. Of this,

Table 1
Area in a 30 m (15 m for each side) buffer along paved roads in each Brazilian biome, estimated amount of sequestered carbon (ton) if the area was restored, and carbon market value, ranging from US\$1/tCO$_2$e to US\$131/tCO$_2$e (World Bank et al., 2016).

Biome	Jurisdiction	Area (ha)	% in urban area	Sequestered carbon (ton)	Minimum carbon market value (US\$)	Maximum carbon market value (US\$)	Minimum Restoration cost (US\$)	Maximum restoration cost (US\$)
Amazon	Federal	32,767.70	1.28	4,915,155.56	18,022,237.04	2,360,913,051.59	1,769,455.80	171,951,782.52
Amazon	State	27,199.25	2.42	4,079,887.59	14,959,587.83	1,959,706,005.80	1,468,759.50	142,730,784.30
Atlantic forest	Federal	61,926.88	7.05	9,289,032.08	34,059,784.28	4,461,831,740.03	3,436,941.84	395,173,999.34
Atlantic forest	State	172,332.08	5.01	25,849,811.61	94,782,642.57	12,416,526,176.67	9,564,430.44	1,099,702,702.10
Cerrado	Federal	56,557.05	1.70	2,827,852.44	10,368,792.28	1,358,311,788.68	3,054,080.70	378,010,355.09
Cerrado	State	118,225.53	2.10	5,911,276.36	21,674,679.97	2,839,383,075.85	6,384,178.62	790,183,974.86
Caatinga	Federal	33,343.15	1.45	500,147.26	1,833,873.30	240,237,402.23	1,810,533.05	199,538,746.86
Caatinga	State	64,686.53	0.92	970,297.95	3,557,759.14	466,066,447.93	3,512,478.58	387,110,070.13
Pantanal	Federal	1334.17	2.00	66,708.38	244,597.38	32,042,256.13	126,079.07	11,403,951.49
Pantanal	State	660.05	1.43	33,002.58	121,009.46	15,852,239.26	62,374.73	5,641,843.38
Pampa	Federal	10,798.89	3.64	539,944.64	1,979,797.00	259,353,406.35	586,379.73	83,755,110.95
Pampa	State	5748.82	7.91	287,441.24	1,053,951.21	138,067,608.95	312,160.93	44,587,273.04
Total		**585,580.11**	**3.33**	**55,270,557.67**	**202,658,711.45**	**26,548,291,199.45**	**32,087,852.97**	**3,709,790,594.07**

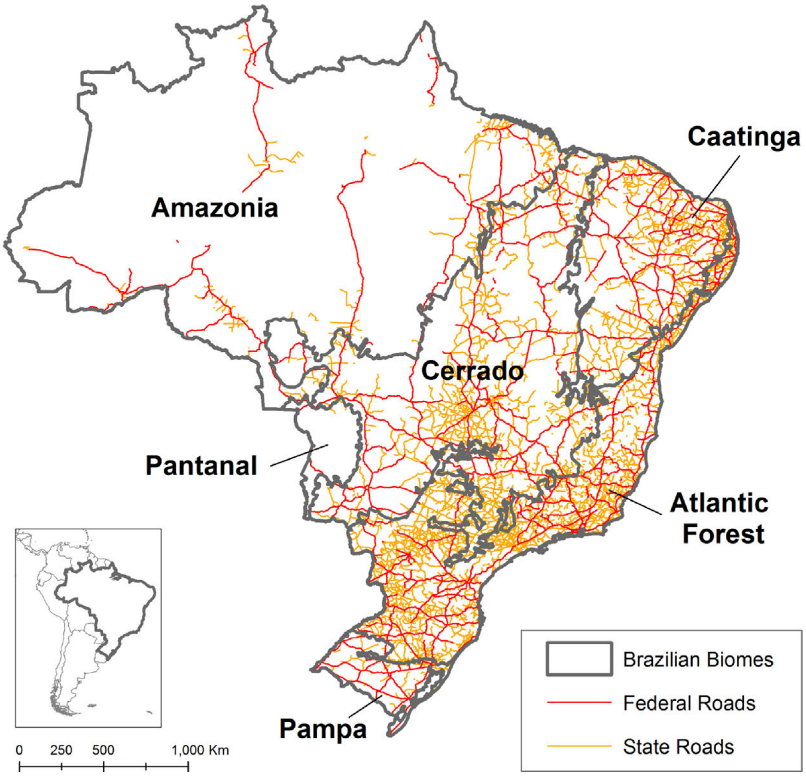

Fig. 2. Distribution of paved state and federal roads within Brazilian biomes: Amazonia forest, Caatinga xeric shrubland, Cerrado savanna, Pantanal wetland, Atlantic Forest, and Pampa grassland.

approximately 3.3% (19,500 ha) are within urban areas. Excluding these urban areas, a total of 566,100 ha would potentially be available for restoration. This corresponds to only ~4.7% of Brazil's commitment under the Paris Agreement but could sequester 55.3 million tons of carbon if properly restored (Table 1, UNFCCC, 2015). The greatest potential is in the Atlantic Forest biome, which combines the greatest road density (40% of the total area to be restored) with the highest carbon stock potential (Fig. 2), followed by the Cerrado and the Caatinga (~30% and ~17%, respectively). Our crude estimate is that the negotiated amount of carbon could range between US\$ 202 million and US\$ 26.5 billion. The estimated cost of restoration ranged from US\$ 32 million to US\$ 3.7 billion (Table 1) and, therefore, the choice of restoration strategy can be crucial for cost-effectiveness, especially under low carbon market values. Considering the values adopted by the Amazon Fund, the negotiated value could reach up to US\$ 1 billion.

Discussion

In Brazil, there is the opportunity to, with a single measure – roadside restoration – restore 566,100 ha of currently underused land, increasing carbon sequestration in a magnitude that would be enough to offset one-fourth of the country's annual emissions from vehicles (MMA, 2014), contributing to carbon stock increases at a regional scale. The restoration costs, despite significantly overlapping with potential negotiated carbon price, can be at least partly offset if the carbon stocks were to be negotiated.

Contribution of roadsides to Brazil's restoration commitments

Brazil can achieve all its commitment to restoring 12 million hectares of land under the Paris Agreement just by enforcing already existing legislation. The enforcement of the "Permanent Preservation Areas" under the Forest Code (Federal Law 12.651/2012), which requires landowners to restore areas along rivers that were illegally suppressed of vegetation cover, would represent 10 million hectares of restored areas in the Cerrado and Atlantic Forest alone (http://www.fbds.org.br/). Similarly, enforcing "Legal Reserves" under the Forest Code, i.e. a specific percentage of original vegetation cover that must be present in farms, depending on the biome where it is located, would represent an additional 21.5 million hectares of restored land (Soares-Filho et al., 2014). Assuming that the Forest Code will not be fully enforced (Roriz et al., 2017), the Brazilian commitment under the Paris Agreement can be achieved using a policy mix approach, i.e. multiple policy instruments to target the single environmental objective of land restoration. In that context, enforcing the legislation on land allotment (Federal Law 6.766/1979), as proposed here, has the potential of restoring almost 566,100 ha of land on roadsides.

In regions where most natural vegetation cover is gone, restoration becomes a key conservation strategy. To avoid a greater impact of global change on Brazilian biomes, Segan et al. (2016) recommend restoration as the best strategy for Atlantic Forest, Cerrado, Caatinga, and Pampa. Here we found the greatest restoration potential along roads in the Atlantic Forest, followed by the Cerrado biome (Fig. 2, Table 1), due to the extension of the road network there. Both are "biodiversity hotspots", i.e. areas that combine exceptional biodiversity with >85% loss of original vegetation cover, and are considered global conservation priorities (Myers et al., 2000). The Atlantic Forest is a top priority for restoration in Brazil given that it is the most deforested biome in the country (only 12–16% of it remain covered by native vegetation, Ribeiro et al., 2009) and the one that hosts 65% of Brazilian population and 80% of its GDP (Brancalion et al., 2012). It is also particularly prone to restoration projects, as it is home to the "Pact for the Restoration of the Atlantic Forest", assembling over 100 businesses and nongovernmental and governmental organizations with the goal of restoring 15 million ha of Atlantic Forest by 2050 (Rodrigues et al., 2009). Another top priority for restoration is the Cerrado biome, where recent estimates indicate that targeted restoration could help to mitigate a major extinction crisis (Strassburg et al., 2017). Cerrado is the Brazilian biome that has lost the largest natural vegetation area; an area larger than the entire Atlantic rainforest (more than 1 million km^2; Fernandes et al., 2016b). Thus, our proposal of restoring roadsides with native species is particularly relevant for these two hotspots. It is also very relevant to Pampa, which is not a hotspot but has also lost most of its original vegetation cover (Andrade et al., 2015).

We do acknowledge that, due to the coarse resolution of our analyses, our calculations are rather crude, as they are based on simplified assumptions regarding area available for restoration (and resulting carbon storage potential). On the other hand, we hope that the first analysis for Brazil as a whole, as we present here, will stimulate researchers or relevant agencies to conduct similar analyses at a finer scale for particular regions, e.g. administrative units. The measurement of relevant parameters at an adequate scale (e.g. site/soil conditions, current degradation state, technical issues), will allow a more precise assessment of restoration potential and costs. Our broad-scale study, while containing inherent uncertainties, does not limit the overall message of the great restoration potential right along the roadside.

Carbon storage potential of roadside restoration

While in many regions of the world carbon is a commodity (see World Bank et al., 2016), Brazil is still studying the implementation of an emissions trading mechanism. Certainly, a Brazilian carbon market would make forest restoration actions more feasible, and this market could be used to finance governmental roadside restoration projects. Regardless of the implementation of a carbon market, climate finance could certainly play a major role in fostering restoration in Brazil.

Currently, Brazil negotiates its leading climate mitigation effort through the Amazon Fund, receiving US$ 5 per ton of CO_2e. On the other hand, most scenario analysis from various studies indicates that a global average carbon price of between US$80/t$CO_2$e and US$120/tCO_2e in 2030 would be consistent with the goal of limiting the global temperature increase to 2 °C (IPCC, 2014; IEA, 2016). This is within the range of prices that we have used in our analysis, showing not only its possible financial benefits for Brazil but also its potential for climate change mitigation globally. Another important mechanism under discussion in international climate negotiations – the Reducing Emissions from Deforestation and Forest Degradation (REDD+) – foresees payments in exchange for forest conservation and restoration (Alexander et al., 2011). Although REDD+ is yet to become fully implemented, voluntary reforestation projects that trade REDD+ credits already exist, including in Brazil, and could encourage a roadside restoration strategy.

Benefits of roadside restoration beyond carbon

In addition to the carbon sequestration potential, roadside restoration has many other environmental benefits. First, it may help to reduce the spread of deforestation along new roads, an indirect impact that was not included in our estimates but that can be very significant. Furthermore, it promotes several ecosystem services, such as soil stabilization, control of noise and light pollution, and enhancing the ornamental value of vegetation. Milton et al. (2015), in their recommendations for roadside vegetation management under a road ecology perspective, highlight the paramount role of native plant species if these ecosystem services of roadside vegetation are to be achieved. In some Brazilian regions, landslides are a major environmental threat, being the cause of one of the worst natural disasters in the country ever, with almost 1000 deaths in 2011 (Zucco et al., 2011). Soil stabilization is therefore of special relevance in Brazil, in particular in the context of the expected increase in extreme weather events due to climate change (PBMC, 2014).

Finally, roadside restoration's role in biodiversity conservation should be emphasized. This may be especially the case in non-forest ecosystems, such as the Cerrado, Pampa, Pantanal and Caatinga, which cover one-third of Brazilian territory and are at high risk of biodiversity losses (Fernandes et al., 2014; Overbeck et al., 2015; Fernandes, 2016). The predominately herbaceous and open vegetation of these biomes, with rather sparse woody species, if present at all, is especially well-suited for roadside vegetation. Besides reducing total restoration costs, this vegetation does not impair visibility, minimizing risks for traveler safety. In our analyses, biomes dominated by non-forest vegetation sum up to almost 50% of the total area to be restored. In landscapes under intense human use, restoring roadside vegetation may provide refuge not only for native plants, but also for other taxonomic groups, such as insects, that might have been regionally lost, and are particularly important for ecosystem functioning. Pollinators for instance have tremendous importance in ecosystem functioning and ecosystem services, especially for animal-pollinated crops (e.g. Van Geert et al., 2010; Novais et al., 2016). The benefits of roadside vegetation have been shown for butterflies, bees, birds and small mammals in other regions of the world (e.g. Hopwood, 2008; McCleery et al., 2015; Milton et al., 2015). Furthermore, as linear systems, roadsides could potentially help connect larger natural areas, increasing movement of plants and animals between habitat fragments (Gilbert-Norton et al., 2010) and promoting the maintenance of genetic diversity and the gene flow between populations (see Mijangos et al., 2015).

It is important to note, however, that the conservation benefit of our proposed roadside restoration could be marginal for some species groups, such as medium to large size animals. A 15-m wide vegetation stripe on each side of the road can still potentially serve as a corridor for these species, but it is often too narrow to sustain viable populations, and may even constitute dangerous traps exposing animals to roadkill (Coffin, 2007). However, for many species (e.g., birds, bats, insects, etc.) this problem can be minor, and it will also vary among the different ecosystems (e.g., grasslands, shrublands, forests, etc.). With appropriate planning, there are methods that can minimize these issues, such as the installation of fences, tunnels, and green bridges for animal crossing in regions of higher risk of roadkill (Lesbarrères and Fahrig, 2012; Rytwinski et al., 2016). Also, as road networks may act as dispersal corridors of non-native species (e.g. von Der Lippe and Kowarik, 2007; Mortensen et al., 2009; Barbosa et al., 2010), the use of native plant species is paramount, just as adequate monitoring and management of roadside vegetation (Milton et al., 2015). If properly managed, restored roadsides may even prevent the dispersal of non-native plant species into adjacent ecosystems, as these species often benefit from altered and exposed soil to settle (e.g. Davis et al., 2000). At any rate, even if restoration will not allow for establishment of the reference ecosystems in all situation, or along the entire roadside (e.g. maintaining a strip of 2–3 meters with low vegetation adjacent to the road), all activities will provide substantial benefits compared to the non-restoration scenario.

Implementation possibilities and perspectives

We suggest targeting roadsides for restoration not only for the many environmental benefits discussed above but also because they are particularly easy to execute. In most cases, federal and state governments are the sole owners of this large, under-utilized real estate. Therefore, law enforcement would be sufficient to hold road construction agencies responsible for the proposed restoration. There is a pressing need for scientifically guided restoration policies, not only of roadside margins but many other abandoned lands in the country. Here we propose, as a starting point, the incorporation of restoration in the management of existing roads and the planning of future road construction and expansions, which under current practices are not properly restored but, at most, revegetated, often with exotic plants (e.g., Fernandes, 2016). The adoption of such a restoration strategy could be extremely important in the future as Brazil has 1,351,979 km of unpaved roads and another 157,309 km of roads to be constructed and paved in the next few years (CNT, 2016). This represents a seven-fold increase in current paved road extent – 211,468 km (CNT, 2016) – used in our current analysis.

By 2050 an increase of 25 million km of roads is expected worldwide, in response to the transportation demand of agricultural production, representing a 60% increase in the current road network (Dulac, 2013). Over 90% of these roads will be implemented in developing countries, such as Brazil, which are exceptionally rich in biodiversity and vital ecosystem services (Laurance et al., 2014). To prevent these highways from jeopardizing important ecosystem services, Laurance et al. (2014) suggest a global strategy of avoiding the construction of roads in areas with high environmental value, while prioritizing construction in areas with low environmental value and where highways could significantly improve agricultural development. The idea is to “avoid the first cut” into new ecologically important areas. In areas where new roads have already been built or where road construction is unavoidable, roadside restoration may help mitigate environmental damage and potentially reduce further clearing on adjacent land.

Altogether, the restoration of roadsides in Brazil means putting to use an immense and readily available potential for carbon sequestration, with other important environmental benefits. Within and beyond Brazil itself, restoration of these currently neglected lands may show to different stakeholders the potential financial and environmental benefits of land restoration, and stimulate the development of restoration techniques and materials in regions where ecological restoration is incipient. Impact of roadside restoration thus clearly should go beyond the land strips along the roads.

Conflict of interest

The authors declare no conflicts of interest.

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