Creating space for large-scale restoration in tropical agricultural landscapes

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Poorly planned, large-scale ecological restoration projects may displace agricultural activities and potentially lead to the clearance of native vegetation elsewhere, with associated impacts on biodiversity and ecosystem services. Yet few studies have considered these risks and the ways in which restoration can increase competition for land. Here, we address this issue by examining whether large-scale restoration of the Brazilian Atlantic Forest could displace cattle production, as a result of land shortages. Although the risks of displacement are indeed high when reforestation is planned in areas with high cattle productivity, we discuss how these risks can be minimized through a combination of productivity increases, a regional restoration planning framework, and the prioritization of marginal agricultural land for restoration. We also consider how restoration can, in some circumstances, be made more economically sustainable by incorporating income-generating activities such as exploitation of timber and non-timber forest products, certification, and payments for ecosystem services.

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The anthropogenic degradation of natural ecosystems, including land-use conversion, has led to widespread loss of biodiversity and has compromised the provision of ecosystem services in landscapes around the world (Cardinale *et al.* 2012). There are now approximately two billion hectares of deforested and degraded land worldwide (Minnemeyer *et al.* 2011). As a consequence of efforts to reverse this trend, ecological restoration is now widely recognized as a global environmental priority (Aronson and Alexander 2013). The Aichi Target 15 of the United Nations Convention on Biological Diversity, an international instrument for the conservation and sustainable use of biodiversity, together with the "Bonn Challenge" – a global restoration initiative – have established a goal of restoring 150 million hectares of deforested and degraded land globally by 2020. The New York Declaration on Forests expands this goal to 350 million hectares restored by 2030. In addition, several large-scale restoration initiatives have emerged around the world in recent years – for instance, the Green Belt Movement in Kenya (de Aquino *et al.* 2011), where millions of hectares of agricultural land are expected to be restored soon (Roberts *et al.* 2009; Rodrigues *et al.* 2011).

In a nutshell:

- Large-scale ecological restoration can displace pre-existing agricultural activities and may drive increased competition for land, resulting in the loss of native vegetation elsewhere
- It is possible to reconcile large-scale restoration and agricultural expansion through improvements in cattle ranching productivity in regions with intense competition for land, such as the Atlantic Forest of Brazil
- The farming sector, agricultural institutions, and planning authorities all have a central role to play in any large-scale restoration program, helping to avoid negative socio-environmental outcomes as a result of poorly planned restoration while promoting compliance with environmental laws
- Further research is urgently needed to study and monitor the effects of large-scale restoration on people and the environment

In many parts of the world, the restoration of ecosystem services and the conservation of biodiversity depend on the success of such projects. Even if only partly successful, such initiatives could become yet another major competitor for land – an increasingly scarce resource that is needed to satisfy the growing demands of a progressively larger and more affluent human population (Smith *et al.* 2010). Consequently, a key challenge in the management of any large-scale restoration project is avoiding the displacement of pre-existing land uses such as agriculture, as this may result in further clearance of native vegetation and loss of biodiversity elsewhere (Meyfroidt and Lambin 2009; Melo *et al.* 2013). This displacement could also produce negative social consequences for the people who have been displaced (Barr and Sayer 2012).

There is evidence that such displacement, or "leakage", has already occurred in some locations. For example, about 39% of the increase in forest cover in Vietnam between 1987 and 2006 appears to have been balanced by commensurate increases in deforestation in nearby countries (eg Laos, Cambodia, and Indonesia; Meyfroidt and

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Figure 1. *The Atlantic Forest, a global biodiversity hotspot despite being highly fragmented. Approximately 30 million hectares in the Atlantic Forest region are used for cattle ranching.*

Lambin 2009). This pattern of displaced land use is also evident in other countries where large-scale restoration occurred (Meyfroidt *et al.* 2010). Yet while the threat of indirect effects of land-use change has received increasing attention in the context of agricultural expansion (eg soybeans and sugarcane in Brazil, Arima *et al.* 2011; cross-biome leakage worldwide, Strassburg *et al.* 2014a), it has received unexpectedly little attention in the context of large-scale ecological restoration. In fact, many legitimate concerns about potential negative consequences of increased competition for land from restoration projects are largely based on anecdotal evidence (Barr and Sayer 2012) and very little spatially explicit information is available on the potential for conflicts over land between agriculture and restoration.

Here, we examine the potential for future competition for land between forest restoration and cattle pastures in Brazil's Atlantic Forest biome and estimate the potential for displacement of cattle pastures. We also consider how any such displacement could be avoided or mitigated at both local and national levels. In particular, we assess alternative ways of reconciling multiple demands for land through increases in the productivity of cattle ranching, based on a case study of the Brazilian state of Espírito Santo. To this we apply alternative scenarios assessing existing state-imposed targets for the expansion of agriculture, plantation forestry, and forest restoration.

The Atlantic Forest is one of the most species-rich biomes on the planet, yet less than 15% of the original forest is left; much of what remains is highly degraded, making this region a national and global priority for restoration efforts. The case study offered by the Atlantic Forest will facilitate exploring the consequences of increased competition for land as a result of large-scale restoration, both in Brazil and across the tropics, and may help in developing a conceptual foundation to promote further advances in research and policy.

Opportunities for restoration in low-productivity pasturelands

The Atlantic Forest is a unique and highly threatened biome, retaining only 8–14% of its original areal cover of 150 million hectares; of the remaining forest fragments, 80% are less than 50 ha in size (Figure 1; Ribeiro *et al.* 2009). Even though it is also one of the top five global biodiversity hotspots, referred to often as "the hottest of the hotspots" (Laurance 2009), it still experiences annual deforestation rates of more than 20 000 ha (Soares-Filho *et al.* 2014). In addition, the Atlantic Forest biome is of great importance for Brazilian society, providing a home for approximately 60% of the national population (IBGE 2012); about 80% of the country's gross domestic product is generated within the Atlantic Forest boundaries (IBGE 2012).

The Atlantic Forest Restoration Pact (AFRP; a group of environmental organizations, private companies, government agencies, researchers, and landowners) in Brazil is a biome-scale restoration initiative aimed at maximizing the benefits of large-scale forest restoration while avoiding negative environmental and social outcomes (Melo *et al.* 2013). The target areas for restoration were selected by the AFRP, based on an assessment of deforested lands included within so-called Permanent Preservation Areas ("APP" in Portuguese) in accordance with the Brazilian Forest Code; totaling seven million hectares, these areas primarily include riparian buffer zones along streams and around springs (where restoration is mandatory), as well as extensive, low-productivity pasturelands with few cattle (Calmon *et al.* 2011). Together, these lands total 17 728 187 ha, providing the basis for the AFRP's stated goal of restoring 15 million hectares of forest within the Atlantic Forest biome by 2050 (Calmon *et al.* 2011; Melo *et al.* 2013). There are currently approximately 30 million hectares of planted pastures in the Atlantic Forest, supporting 36 million head of cattle at an average stocking rate of 0.82 animal units (AU) per hectare (1 head equals 0.7 AU; PROBIO 2009) – a very low level of production efficiency by international standards (Strassburg *et al.* 2014b).

Restoration success will presumably vary considerably across the Atlantic Forest biome for several reasons, including variability in both natural soil conditions (Sobanski and Marques 2014) and historical human use. Restoration is likely to be more effective (ie supporting the long-term recovery of a species-rich, functioning forest ecosystem) and to require fewer expensive interventions (eg soil preparation, active plantings, clearance of exotic trees and grasses to prevent competitive exclusion) in areas that have been subject to less intense and extensive levels of historical use and in areas that are closer to forest remnants, which provide source populations of native species. Given these constraints, any large-scale restoration program should also consider prioritizing areas based on restoring local ecosystem services (eg hydrological services and prevention of soil erosion) or protecting endemic biodiversity (eg through the creation of forest corridors to connect isolated reserves), even if high levels of active management are needed.

In an effort to account for such considerations, the member organizations of the AFRP have developed maps prioritizing areas for restoration based on the demands for different ecosystem services, including the supply of drinking water to urban populations and suitable areas for carbon sequestration projects. Opportunities for increasing landscape connectivity and low-productivity pastures on marginal sloping land to avoid competition for land were also prioritized, as were potential areas for offsetting the loss of native forests, according to the Brazilian Forest Code (Brancalion *et al.* 2013). Indeed, landholdings in the Atlantic Forest must maintain 20% of native vegetation cover as so-called Legal Reserve, and if this requirement is not met, the deficit must be offset by restoring degraded lands, or by acquiring or renting remnants of equivalent size (Brancalion *et al.* 2013). Although more ecologically sensitive areas should be strictly protected and should therefore be restored to meet conservation goals, large-scale restoration elsewhere can benefit from increased revenues through sustainable management. Innovative models of forest restoration have been developed to create incentives for farmers to invest in restoring degraded areas, for example by allowing the sustainable extraction of both timber and non-timber forest products, coupled with payments for ecosystem services (Brancalion *et al.* 2012). The AFRP estimates that more than three million local jobs could be generated as part of the restoration process (Brancalion *et al.* 2013), while improvement of degraded watersheds has the potential to reduce the cost of treating drinking water by a hundredfold (Tundisi 2014).

Atlantic Forest and cattle pasture restoration in Espírito Santo, Brazil

The Brazilian state of Espírito Santo provides a valuable case study for understanding the potential challenges and solutions involved in accommodating new restoration areas in a region where land is an increasingly scarce resource. The state government, supported by both the State Institute for Environment and Hydrological Resources (IEMA or Instituto Estadual do Meio Ambiente e Recursos Hídricos) and the Agroforestry and Forestry Defense Institute (IDAF or Instituto de Defesa Agropecuária e Floresta), has recently published the "Reforest" Program ("Reflorestar" in Portuguese) with the aim of restoring 236 000 ha of forest through large-scale restoration and conservation by the year 2025. At the same time, the state development plan calls for a 284 000-ha expansion of the areas devoted to agricultural crops and a 400 000-ha expansion of forest plantations (PEDEAG 2008).

These proposed changes in land use take place within a mosaic of existing agricultural landscapes, made up of both large and small landowner–producers. In 2010, the state territory (4.6 million ha) consisted mainly of pasturelands (41%, 1.9 million ha), croplands (19%, 862 000 ha), native forests (21%, 990 000 ha), and silvopastoral systems (11%, 487 000 ha; Lorena *et al.* 2014); other land uses include rocky areas (2.6%), other vegetation (2.3%), urban areas (1.5%), and water bodies (1.2%). Here, we assessed the potential carrying capacity of pastureland in different regions of Espírito Santo to accommodate 684 000 ha of planned agricultural and forestry expansion (284 000 ha + 400 000 ha; Scenario 1) or the same agricultural and forestry expansion with an additional 236 000 ha of native forest restoration (Scenario 2). We then examined how different increases in pasture productivity could, in theory, provide new areas of land to satisfy state targets for both arable crops and restored forest. Pasturelands in the state were divided into polygons, and from these we extracted the potential forage grass biomass growth (kilograms per hectare), using a spatial database developed by the Food and Agriculture Organization and the International Institute for Applied Systems Analysis (FAO/IIASA 2010). We converted biomass figures into estimates of potential carrying capacity (AU per hectare) using standard coefficients for grazing efficiency (8 kg day^{-1} dry biomass consumption per head and 50% pasture grazing efficiency).

Assuming that beef production remained constant (PEDEAG 2008), we considered a target for improving pasture productivity in a region to be feasible if two conditions were met: (1) the increase in productivity is equal to or less than double the average productivity until the year 2025, and (2) the final average stocking rate is less than or equal to 80% of the carrying capacity (the potential number of animals per unit area; see WebPanel 1 for details). We viewed these as conservative, practical limits for changes in cattle productivity, given that we only considered fully grass-based systems; higher stocking rates could be achieved with supplementary feed or confinement systems, but we did not consider these approaches because of animal welfare considerations. Our approach for modeling land-use dynamics to account for the large-

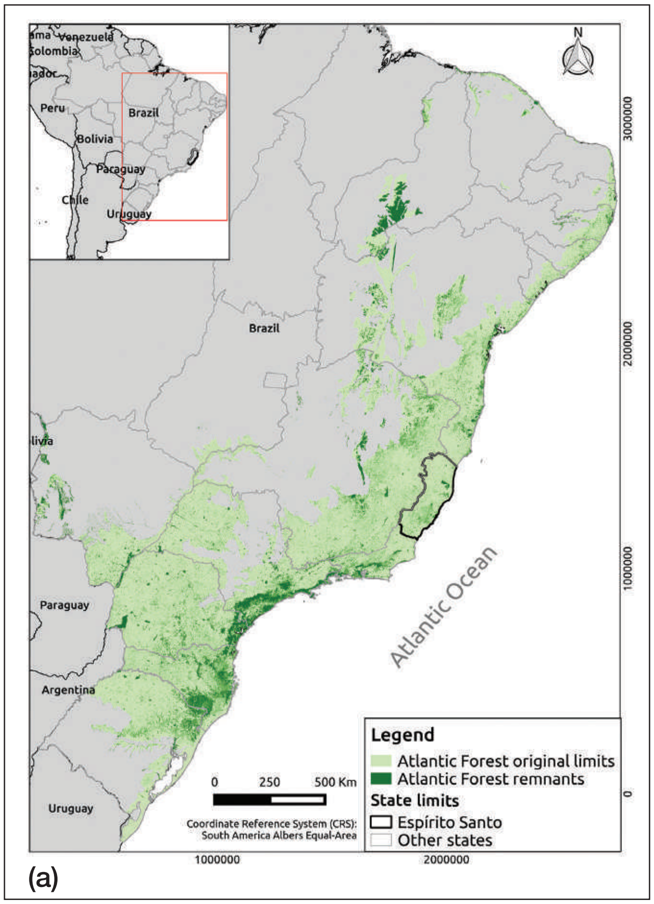
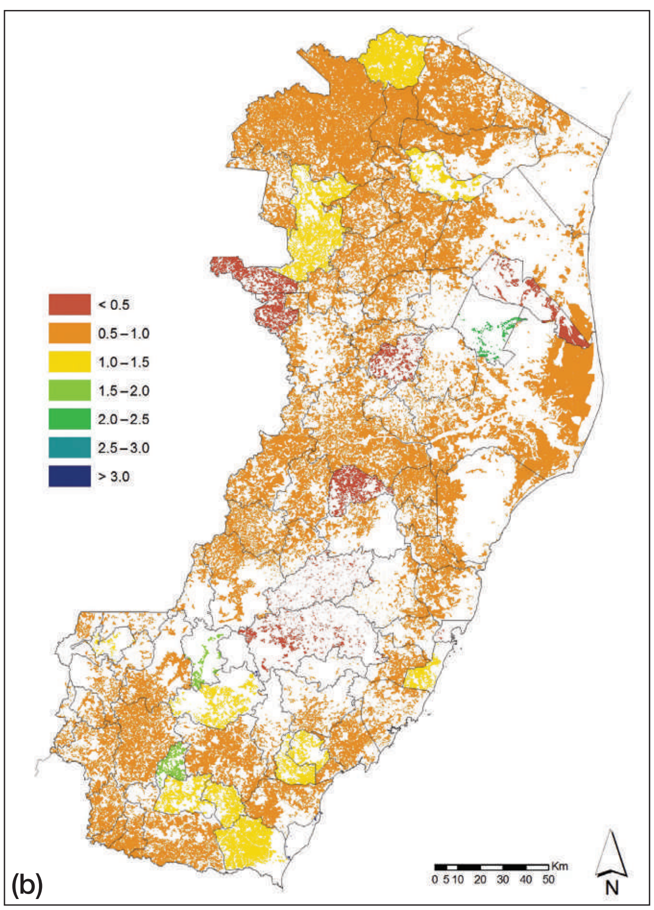


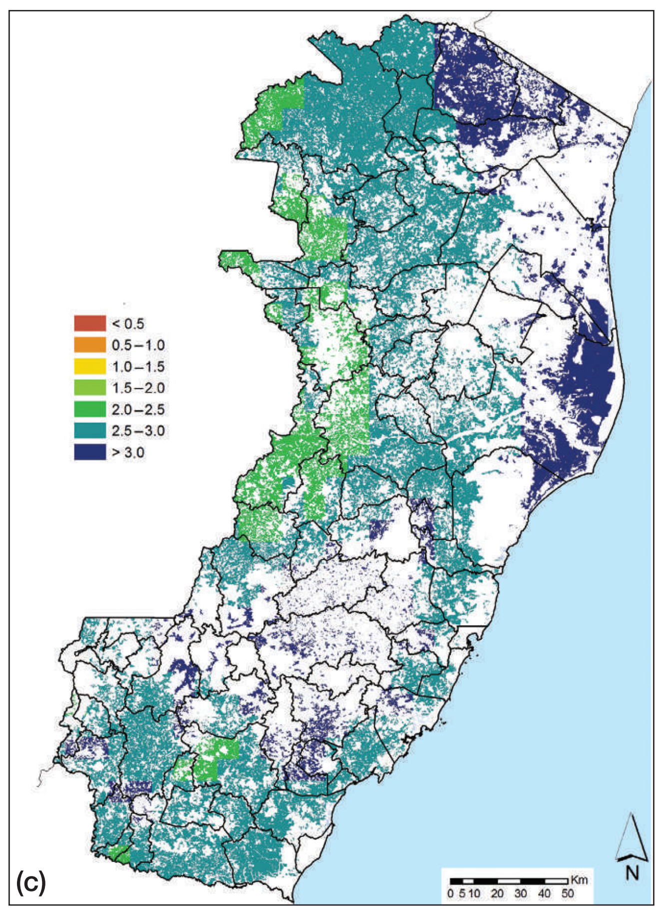
Figure 2. Map of the Brazilian Atlantic Forest (a) based on data from SOS Mata Atlantica (2014). Areas in light green and dark green show the original limit of the Atlantic Forest and its current remnants, respectively. The state of Espírito Santo is marked with a black outline. Current (b) and potential (c) pasture productivity in Espírito Santo in AU ha^{-1} are shown on a scale where red represents low productivity (less than 0.5 AU ha^{-1}) and blue represents high productivity (more than 3 AU ha^{-1}).

scale restoration of native ecosystems can easily be adapted to other scenarios, including situations where beef production is likely to increase.

We found that the potential carrying capacity of existing pastures in the state is 5.29 million AU, or 2.77 AU ha^{-1}. By comparison, the current cattle herd in Espírito Santo is 1.42 million AU (only 27% of the estimated capacity), with an average productivity of 0.74 AU ha^{-1} (Figure 2 and Table 1). Most of the state is characterized by low levels of cattle productivity but with considerable potential for growth (Figure 3), further reinforcing the notion that increasing cattle productivity in these areas is a viable option to spare other areas for restoration (Figures 4 and 5).

In Scenario 1, a 57% increase in cattle productivity (equivalent to an increase from 0.74 to 1.16 AU ha^{-1}) is necessary to meet state goals for agriculture and forest plantations while maintaining current levels of beef production. In Scenario 2, a 93% increase in cattle productivity would theoretically "spare" enough land to meet





agriculture and forestry expansion goals as well as to restore 236 000 ha of native forests over 15 years (between 2010 and 2025). This would mean reaching 52% of the pasturelands' carrying capacity in 15 years.

The risks of agriculture displacement (and therefore potential for indirect land-use change and associated social problems) following large-scale restoration vary between regions within Espírito Santo. Competition for land between agriculture and forest restoration is likely to be highest in the coastal northern region, Litoranea Norte, which contains more high-productivity pasturelands (Figure 2 and Table 1) and is home to a variety of other highly profitable agricultural activities (*Eucalyptus*, coffee, and sugarcane). By contrast, competition for land is likely to be much less intense in the northwest region, given the area's relatively low levels of pastureland productivity (Figure 2 and Table 1).

Agricultural development, large-scale restoration, and competition for land

Reconciling agricultural development, forest conservation, and restoration is one of the greatest challenges for environmental and social sustainability in the face of current and future competition for land. If poorly managed, large-scale restoration – like any externally motivated and unfamiliar type of land use – could result in unequal distribution of benefits, leading to increased inequality among the original landowners and the potential displacement of more marginalized community members (Barr and Sayer 2012). In addition, any loss of commodities resulting from the original land use could be compensated by the expansion of new production areas elsewhere, if demand for those original commodities remains high (ie indirect land-use change). Should this expansion occur in areas containing old-growth vegetation, then this could result in negative impacts on biodiversity and ecosystem services, even in situations where there is a net increase in forest cover (eg Ferraz *et al.* 2014).

The evidence for indirect land-use change driven by the expansion of land uses other than restoration remains ambiguous. While some authors have demonstrated that soybeans and sugarcane lead to displaced deforestation in the Amazon (Arima *et al.* 2011), others have been unable to show leakage of soybean expansion into the Cerrado (a large area of subtropical and tropical savanna) of Mato Grosso after increased enforcement in the Amazon (Macedo *et al.* 2012). Some studies found no evidence of protected area expansion in the Amazon causing deforestation elsewhere (Soares-Filho *et al.* 2010). There are also considerable methodological challenges associated with

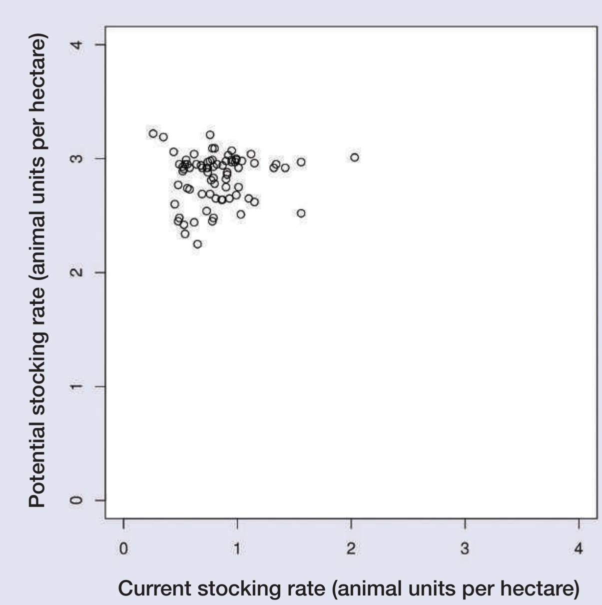


Figure 3. *Much of Espírito Santo is currently characterized by low stocking rates (expressed in animal units per hectare on the* x *axis) but high potential stocking rates (in animal units per hectare on the* y *axis), further reinforcing the major potential for increasing cattle ranching productivity while sparing land for other uses.*

Table 1. Summary of land-use indicators, based on the two scenarios analyzed in this study

Land-use indicators	*Current*	*Scenario 1 (increasing cattle ranching productivity to increase croplands and forest plantations)*	*Scenario 2 (increasing cattle ranching productivity to increase croplands and forest plantations and to meet restoration targets)*
Cropland area (thousand hectares)	862	1146	1146
Plantation forest area (thousand hectares)	487	887	887
Pastureland area (thousand hectares)	1909	1225	989
Stocking rate (AU per hectare)	0.75	1.16	1.44
Sustainable stocking capacity (%)	27	42	52
Total native forest cover (thousand hectares)	990	990	1226
Restored forest area (thousand hectares)	0	0	236
Native forest cover increase (%)	0	0	24

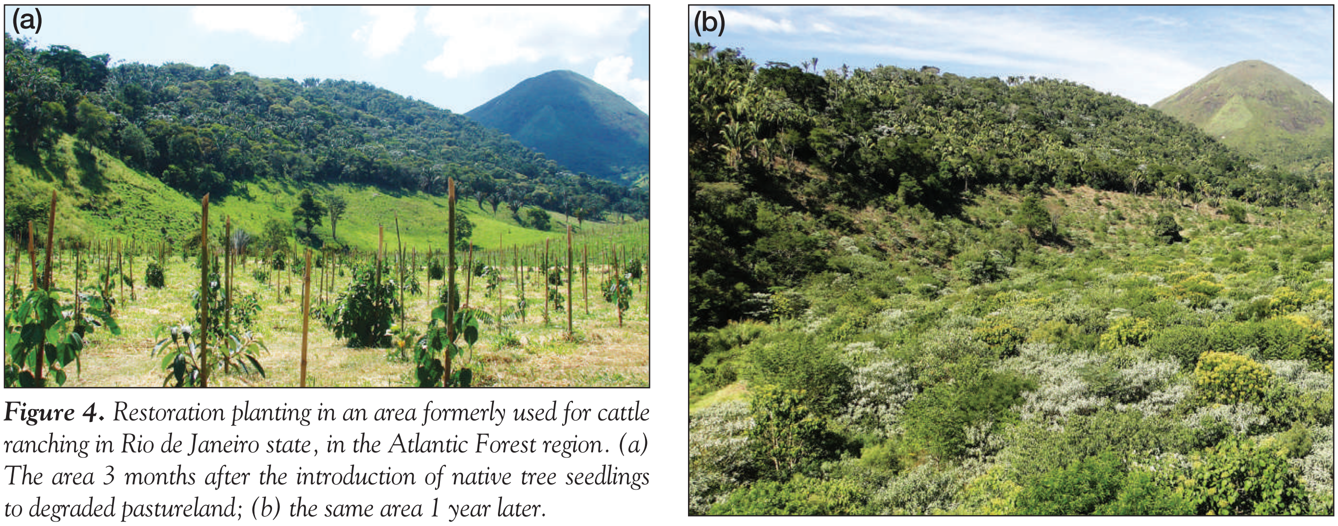


Figure 4. *Restoration planting in an area formerly used for cattle ranching in Rio de Janeiro state, in the Atlantic Forest region. (a) The area 3 months after the introduction of native tree seedlings to degraded pastureland; (b) the same area 1 year later.*

assessments of leakage (Henders and Ostwald 2014). However, the potential for major re-allocations in land use affecting vegetation clearance rates in neighboring regions clearly remains a risk, especially in the context of ongoing transport and other infrastructure developments occurring in the Amazon and Cerrado. For example, livestock from the Atlantic Forest region has likely been displaced to the Amazon and Cerrado after the expansion of more profitable land uses such as sugarcane (Lapola *et al.* 2014), and absolute deforestation rates in the Cerrado recently surpassed those in the Amazon, where environmental enforcement is more rigorous (Soares-Filho *et al.* 2014). As such, restoration efforts in the Atlantic Forest at the scale of millions of hectares could possibly have a similar effect, resulting in further clearance of old-growth fragments in the Atlantic Forest or in the neighboring Cerrado.

Sustainable increases in production on current agricultural lands are commonly suggested as a key part of efforts to ease the conflict between agricultural expansion and the conservation of natural ecosystems (Smith *et al.* 2010; Latawiec *et al.* 2014a); increases in cattle ranching productivity often provide the most promising opportunity to spare large areas of land from deforestation (eg Cohn *et al.* 2014; Strassburg *et al.* 2014b). Nevertheless, the implications of a land-sparing approach with respect to large-scale restoration have been poorly explored. Here we show that in the case of the Atlantic Forest, plausible increases in cattle productivity, the dominant and least productive land-use type in the region, could free up enough land to meet large-scale forest restoration targets in Espírito Santo, helping to restore critical ecosystem services while providing positive returns for landowners – including small-scale cattle ranchers – and the wider development of the regional economy.

Yet there are several essential pre-conditions for the success of any such "land sparing", with coupled improvements in agricultural productivity (whether in cattle ranching, as in this case, or another large-scale agricultural system) and restoration. First, restoration efforts and improved agricultural practices incur start-up costs and require necessary technical support and specialized knowledge, especially in areas that are highly degraded or are isolated from native forest. Even though these invest-

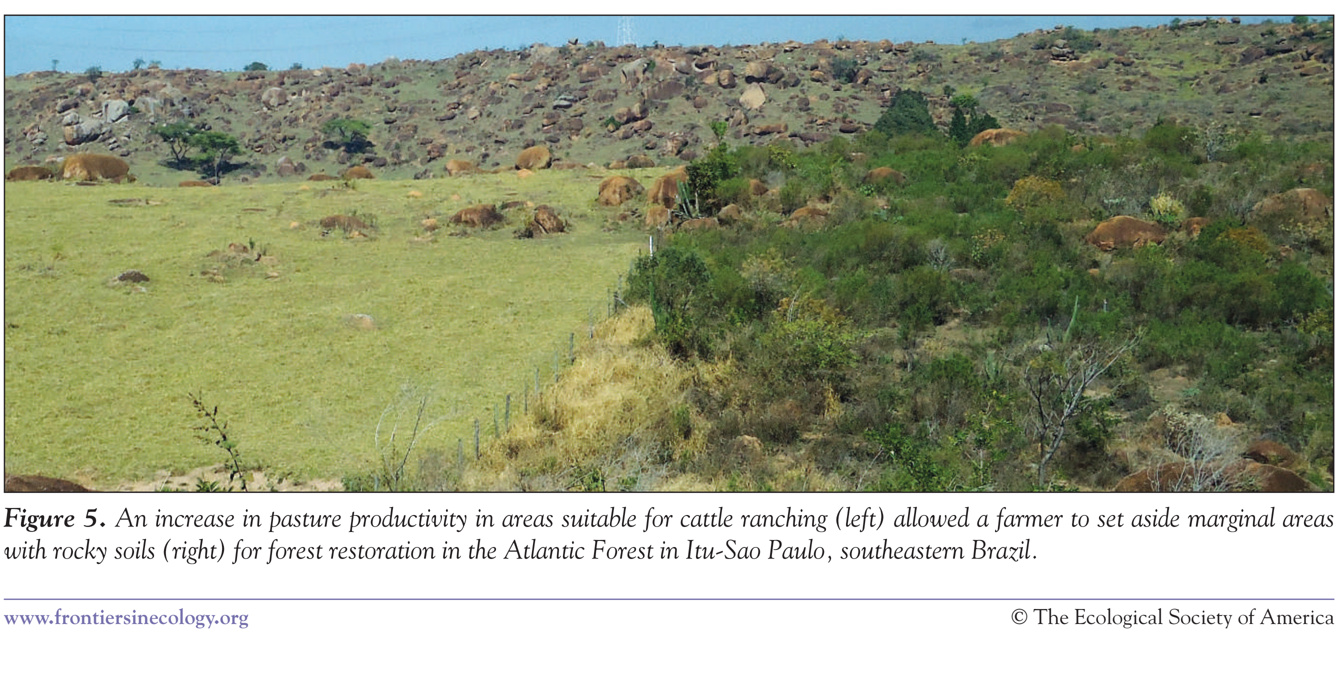


Figure 5. *An increase in pasture productivity in areas suitable for cattle ranching (left) allowed a farmer to set aside marginal areas with rocky soils (right) for forest restoration in the Atlantic Forest in Itu-Sao Paulo, southeastern Brazil.*

ments may be recovered relatively quickly (eg 3–4 years; Brancalion *et al.* 2012), there are often problems with initial financing as well as with the educational and cultural barriers involved in adopting more technologically advanced agricultural systems (Rodrigues *et al.* 2011; Brancalion *et al.* 2012; Latawiec *et al.* 2014b).

Second, improvements in the benefits and profitability of both agriculture and restoration forestry need to be closely monitored and integrated across entire properties and landscapes, especially in areas where competition for land is strong. Restoration forestry needs to become an economically viable land use, where the exploitation of timber and non-timber forest products, as well as the possibility of payments for ecosystem services from restoration sites, could provide returns that are comparable to those from the preceding agricultural activities (eg Brancalion *et al.* 2012; WebPanel 2).

Third, any intervention to improve the profitability of one major land use (eg cattle ranching) must be accompanied by effective regulatory policies enforcing strict protection for remaining areas of native vegetation. Without such measures, increased productivity can easily lead to increased deforestation (ie the "rebound effect", where increased productivity – and hence profitability – leads to an increase in demand for more land and still greater productivity; Meyfroidt and Lambin 2009; Rudel *et al.* 2009). Improvements in the profitability of agriculture may also escalate future costs of conservation and restoration activities as increases in land rents outpace investments in conservation incentives (Phelps *et al.* 2013).

Finally, improvements in the productivity of one agricultural sector must not result in negative social consequences: for example, disenfranchising smallholders following increases in land prices, failing to incorporate original landowners in any process of technological improvement, or neglecting to protect the livelihoods of those involved in other, less-profitable farming activities (eg staple crop production, fruticulture, and agroforestry) that are key to meeting local and regional food security needs.

An integrated suite of policies should guarantee that large-scale restoration delivers long-term environmental and social benefits: strategic territorial planning (eg through Brazil's economic–ecological zoning plans), improved enforcement of existing environmental regulations, land-tenure security, monitoring of land-use practices, incentives for job provision through restoration work, and other social welfare and justice considerations (Calle *et al.* 2012). Strategic planning for enhanced landscape connectivity and prioritizing restoration in areas of high conservation value must also be taken into account if large-scale restoration is to deliver long-term benefits for biodiversity (Banks-Leite *et al.* 2014). Although we have focused here on cattle production, the risks and opportunities associated with large-scale restoration are relevant to other agricultural systems as well. There may be situations, even in areas dominated by extensive cattle ranching, where displacement effects can be avoided by switching to another production system. Indeed, natural resource managers should consider the range of activities and approaches that may contribute toward the improved use of any system, including diversification and processing of commodities. It then becomes possible to set aside areas for large-scale restoration, thus ensuring the protection of both local and regional ecosystem services while avoiding potential negative displacement.

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