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Balancing land sharing and sparing approaches to promote forest and landscape restoration in agricultural landscapes: Land approaches for forest landscape restoration

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ABSTRACT

Forest and landscape restoration (FLR) could benefit from the land sharing/sparing approaches to support decisions. We discuss four questions potentially shaping FLR outcomes in agricultural landscapes in the context of land sharing/sparing decisions: (1) Which are the main focuses of restorative interventions?; (2) Which kind of restored forests should these interventions target?; (3) Which restorative interventions should be implemented and where?; and (4) What are the major factors influencing restoration outcomes? Some restorative interventions embraced by FLR may compete with specific land uses and thus require careful planning to minimize trade-offs and maximize synergies. Decision making on the restorative intervention combination needs considering the spatial distribution and configuration of the final land uses in the landscape together with its social context and a multi-stakeholder process. Ultimately, finding the right balance between land sharing/sparing approaches will also require navigating governance issues that regulate FLR implementation.

The promise of forest and landscape restoration

Forest and landscape restoration (FLR) has emerged as a landscape management framework to recover large extents of deforested and degraded lands and to contribute to human wellbeing (Lamb, 2014; Chazdon et al., 2017). FLR responds to the Bonn Challenge, a global initiative to bring 150 million hectares of deforested and degraded land into restoration by 2020, and 350 million hectares by 2030; pledged by 49 countries, nine private sectors, and some subnational jurisdictions (Bonn Challenge, 2019). FLR offers benefits in terms of biodiversity conservation, ecosystem services, and agricultural production, which can be potentially reconciled in the same landscape (Sayer et al., 2013; Rey Benayas and Bullock, 2015). Multi-functional landscapes may include several coexisting land use types such as protected native forest remnants, naturally regenerated forests, agroforests, mixed species plantations, and commercial monoculture plantations, which collectively represent different 'restorative interventions' (Aronson et al., 2017; Laestadius et al., 2015). Nevertheless, most FLR projects ultimately involve a tree/forest cover increase as the basis of the landscape transformation process (Brancalion and Chazdon, 2017). A critical factor for enabling its implementation is land availability, since most of the >2 billion hectares of landscapes potentially available for FLR is currently occupied by agricultural land use (Stanturf et al., 2015) and this area will still increase in the near future (Song et al., 2018). Thus careful land planning and management – including financial expectations of landowners – is needed to accommodate additional tree/forest cover without bringing serious setbacks for people (e.g., land grabbing), and for the environment across different scales (e.g., leakage) (Grau et al., 2013; Latawiec et al., 2015; Brancalion and Chazdon, 2017).

Expanding tree cover in the landscape has been showed to increase productivity and improve livelihoods and biodiversity, but it may prevent intensive agriculture due to restrictions to mechanization; however, little is known about how existing land uses have to be modified to accommodate these more trees (Fairhead et al., 2012; Latawiec et al., 2015). In this context, important questions can potentially shape FLR outcomes in the context of land

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sharing/sparing management approaches proposed for reconciling biodiversity conservation and agricultural production (Green et al., 2005). Land sharing aims to integrate both objectives on the same land, while land sparing aims to combine high-yield farming in one place and natural protected areas in other place to prevent conversion of natural habitat to agriculture (Fisher et al., 2008; Phalan et al., 2011). Impacts of land sharing/sparing approaches on biodiversity conservation (Kremen, 2015; Goulart et al., 2016; Seppelt et al., 2016) and on more general environmental issues (Grau et al., 2013; Sayer et al., 2013) have been discussed, but implications with respect to large-scale restoration have been poorly explored (but see Latawiec et al., 2015). These two approaches may be discussed in the FLR context and help understanding their implications for ecosystem services and benefits for local livelihoods (Rey Benayas and Bullock, 2012). Here, we first explore challenges and opportunities arisen from the land sparing/sharing approaches in relation to which and where restorative interventions should be implemented in FLR in agricultural landscapes. Next, we discuss policy guidelines to minimize undesirable trade-offs and maximize synergies among these interventions and land management options in a large-scale restoration context to attain sustainable, multi-functional landscapes.

Land management approaches and forest and landscape restoration

Considering land sharing/sparing as binary endpoints rather than two opposite ends of a continuum (Grau et al., 2013; Fisher et al., 2014; Goulart et al., 2016) has made this debate irresolvable and problematic because they are the extremes of what is biophysically possible in a landscape, and realistic options are usually between those extremes. FLR is not just restricted to either biodiversity conservation or agricultural production objectives. Inclusion of ecosystem services other than agricultural production and specific benefits to local livelihoods incorporate new dimensions to the comparison of land management approaches.

Some restorative interventions in the FLR approach may compete against previous agro-pastoral land uses and thus require careful planning to minimize undesirable trade-offs and maximize synergies, as social particularities incorporate trade-offs in decision-making (Metzger et al., 2017). Opportunities for implementing FLR arise from the widespread distribution of low productivity pasturelands in steep slopes, which could be reconverted to native forests through natural regeneration at lower costs and reduced impacts on production (see Box 1), and the production gains resulting from the establishment of woodlots and inclusion of trees in a agro-pastoral systems. But some constrains emerge from the loss of agricultural production resulting from the reconversion of agro-pastoral lands to native forests, and the implementation costs of restorative interventions. In the agricultural landscapes where FLR focuses, the challenge remains practical, and there are some questions that are mutually related and cannot be fully answered independently in order to support decisions on FLR (Fig. 1):

1. Which are the main focuses of the selected restorative interventions? FLR restorative interventions may bring up different focus (e.g., biodiversity, ecosystem functions, specific goods and services, and livelihoods). For instance, if the intervention is focused on recovering biodiversity (e.g., ecological restoration to create habitat for some species), both sharing and sparing may result in no net gain and even loss of particular species as sharing may favor tolerant and open field species while sparing may favor forest-specialist species (Phalan et al., 2011). At the same time, choosing between sharing/sparing to accommodate gains in tree/forest cover in the landscape may alter ecosystem functions that depend on large spatial scales to support ecosystems services (Fisher et al., 2014; Goulart et al., 2016), such as water provision, which could be affected by locating short-rotation monoculture tree plantations in particular location of the basin (Little et al., 2015). Sparing would be more useful to restore landscapes that aim to including areas of high conservation value while sharing may be a better choice when the productive landscape already supports a relatively high proportion of the native biodiversity in the region (Montoya-Molina et al., 2016), and offers opportunities when FLR is focused on sensitive species (Phalan et al., 2016). Sharing may also help to restore biodiversity values linked to cultural landscapes (Rey Benayas and Bullock, 2012) and offers opportunities when FLR is focuseddi on ecosystem services or functional connectivity that depends on remnant forests configuration in the landscape (see 3). The different focuses of selected restorative interventions will determine specificities on the structure and functions of the tree cover type to be restored in the landscape.

2. Which kind of tree cover should restorative interventions target? Ultimately, FLR is about restoring the essential ecosystem functions that sustain landscape functionality and productivity from which people rely and contribute to solving global challenges (Bonn Challenge, 2019). But different restorative interventions would produce different tree cover types. In this context, the adoption of sharing/sparing approaches may favor tree cover types holding distinct diversity, composition, and structure. For instance, under specific landscape conditions or locations, we may want bringing native forest back to a pre-disturbance stage (i.e. ecological restoration). In a sharing context, interventions may target integrating a managed forest and agricultural land uses in the same space and time (e.g., silvopastoral systems, shaded coffee, living fences). Thus, dissimilarities of structure and biodiversity between restored and reference ecosystems may be tolerated to sustain a reasonable functioning and to provide ecosystem services (Chazdon, 2008), so FLR success should not be measured based solely on the similarity to reference ecosystems, as for ecological restoration. Meanwhile, a sparing context would imply laborious and, sometimes, expensive, efforts to restore the attributes of the reference forest (McDonald et al., 2016), and restoration areas may have to be set aside from agro-pastoral land uses to support a full recovery. Both targeted forests and land management approaches will be useful for FLR, depending on the ecological and socio-economic context that will determine the spatial scale and which and where the restorative interventions should be implemented (see 3). The social context, associated to land tenure and access to natural resources, would determine or at least constraint how, when and where financial resources will be used and which kind of restorative interventions would be attractive to local people.

3. Which and where restorative interventions should be implemented? Any choice that social actors make regarding sharing/sparing will affect the resulting map of restorative interventions and their related scenarios. Opportunities for FLR from land sharing/sparing would arise depending on the focus and configuration of the restorative interventions. Sparing schemes are usually employed in the contexts of biodiversity-offsetting policies, compliance with legal instruments, and set-aside areas established by environmental NGOs to recover the habitat of targeted species or private landowners through natural private reserves or conservation easements, whereas sharing approaches are mainly used in the context of agroforestry, agroecology, and forestry. As commented above, interventions under sparing schemes are expected to preferentially target the full recovery of ecosystem attributes, but this depends on where (e.g., close to remnant forests to favor recolonization) and which interventions are implemented (e.g., natural regeneration or using high-diversity tree plantings of native species). Outcomes for ecosystem services following the full range of restorative interventions can be diverse and difficult to

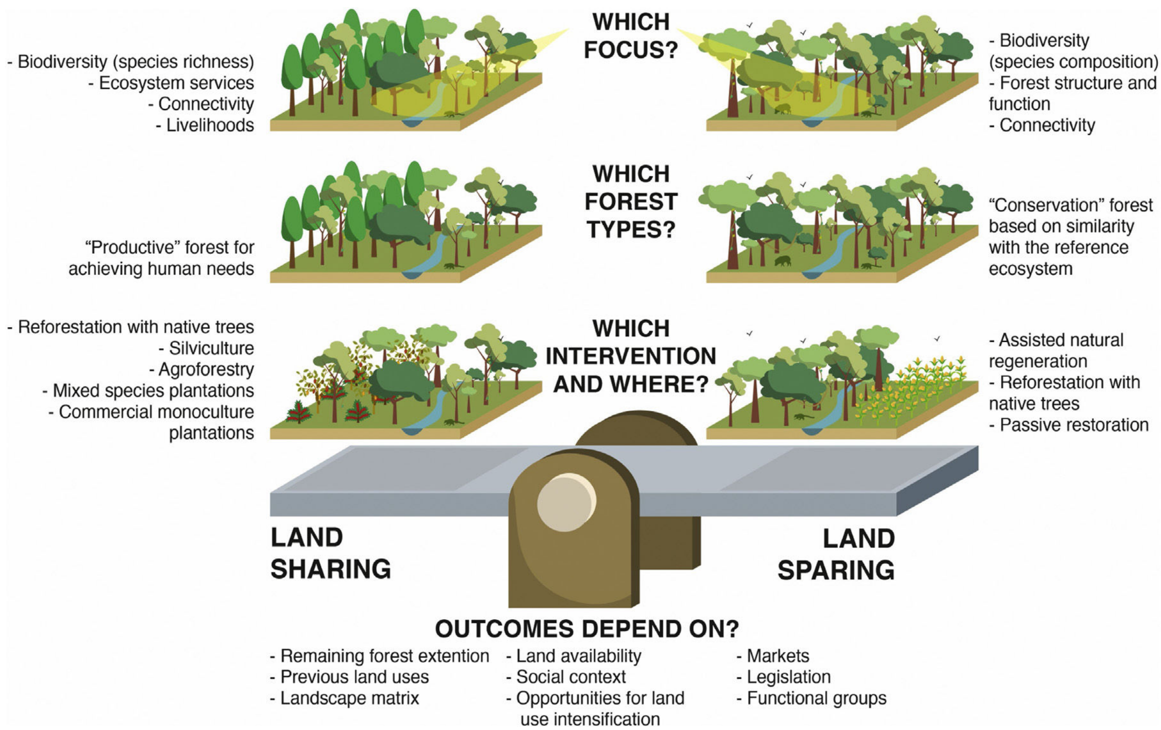


Fig. 1. Four critical questions to support decisions on forest and landscape restoration. The questions are illustrated with examples of responses that hint forces pulling FLR implementation under the two endpoints of the land sharing/sparing gradient.

predict (Fig. 1). In addition, the appropriateness of sharing/sparing is influenced by the biophysical characteristics of landscapes. For instance, mountainous regions may offer more opportunities for sparing, since marginal agricultural lands in steep slopes can be easily set aside to recover native ecosystems through natural regeneration (see Box 1). In regions dominated by intensive agriculture, policy instrument mandating or encouraging the recovery of native ecosystems in environmental fragile areas may foster sparing as well in small portions of the landscape (Rodrigues et al., 2011), while substantial increases in tree cover will rely in sharing approaches. Social actor's selection of restorative interventions and where in the agricultural landscape they are implemented will drive the outcomes of the future restored forest landscape.

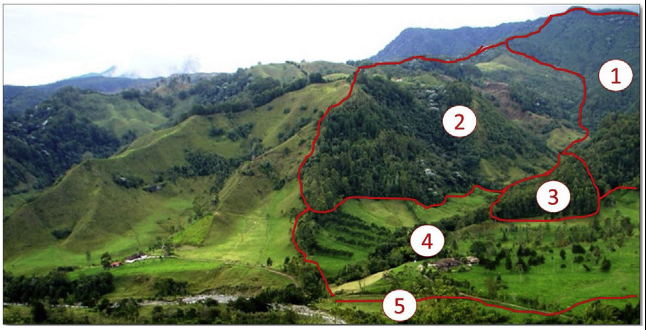
4. What are the main factors influencing restorative intervention outcomes? Finally, the selection among sharing/sparing approaches and their activities will be also related to factors that influence restoration outcomes. Configuration of the landscape to be restored, namely the proportion and spatial distribution of the remaining natural forests in the surrounding matrix, would determine these outcomes. For instance, ecological restoration should focus (at least on its first stages) on establishing new forested areas that provide a vegetation structure able to support water-, soil-, and climate-related ecosystem services while providing habitat for wildlife (see 1), especially if total remaining native forest cover in the landscape is low (<30%; Banks-Leite et al., 2014). These areas may be better restored under sparing schemes while sharing schemes may be used in fragmented landscapes that still maintain some proportion of forest cover. These fragmented landscapes are very common in the tropics, where restorative interventions usually work at local scales and focus on particular landscape components (e.g., riparian or headwater areas) or functions (e.g. landscape connectivity for biodiversity), but allowing production (Meli et al., 2017). If there is very little remaining natural forest, FLR goals could increase forest extent and quality in the landscape (Hodgson et al., 2011), but also enhancing the landscape matrix through wildlife-friendly agriculture (Melo et al., 2013; Crespin and García-Villalta, 2014; Box 1) and considering also individual isolated trees or small forest patches. In addition to transforming 'simple' crops and pastures to agroforestry systems through increasing diversity, which is a pillar of FLR, wildlife-friendly agriculture may involve biodiversity-based agricultural practices, learning from traditional farming, changing from conventional to organic agriculture, and restoring or creating specific elements such as hedgerows to benefit wildlife and particular ecosystem services (Rey Benayas and Bullock, 2012; Rey Benayas et al., 2019; Box 1). All this could help a small scale but also are needed for intensive agriculture are needed. Both approaches may overlap. The surrounding matrix will determine land availability and the opportunity costs for restoration.

At the same time, social information is also critical and should be combined to understand how species respond to different land-use configurations. In a FLR context, supporting sharing or sparing can be socially controversial. Thus, even improving livelihoods for people, opportunities should be also evaluated in the context of market, institutional and political factors, to be appropriately selected for different environmental and socioeconomic contexts and sustainable in time and (Brancalion et al., 2016). For instance, sparing policies may convey governments to solve initial financing and educational and cultural barriers for producers (mostly the local ones) to adopt more technologically advanced agricultural systems (Brancalion et al., 2012; Latawiec et al., 2014). Finally, land sharing/sparing decisions in FLR should also consider stakeholder preferences and livelihoods, while navigating conflicts among stakeholder interests and power asymmetries among them.

Recommendations for forest and landscape restoration in the tropics

FLR approaches will depend not only on degradation levels but also on the desired outcomes (Chazdon, 2008), working scales, and stakeholders' interests. Typically, FLR will need both land sharing and land sparing to fulfill its specific goals and achieve

Box 1: Example of a Forest and Landscape Restoration program using different land sharing/sparing approaches to accommodate new tree cover extent in a previously deforested landscape in the Colombian Andes.



The farm in the left represent a typical farm in the region, where most of the native forests were converted to extensive pasturelands. The farm in the right side had a similar land use configuration to its neighbor, but have been submitted to different types of restorative interventions in the last 20 years: *Conservation*: the native forest fragments remaining in the very steep slopes of the farm have been protected against further disturbances (1); *Restoration through land sparing*: the areas with low productive potential (e.g. steep slopes) have been abandoned for natural regeneration (2) and areas of high environmental importance (e.g. riparian buffers) have been restored through mixed-species plantations (5); *Restoration through land sharing*: pasturelands in areas with higher productive potential (e.g. flatter areas with better soils) have been converted to silvopastoral systems (4) – submitted to an ecological intensification process to increase productivity and compensate for the loss of pasture area –, and eucalypt woodlots (3). The remarkable increase in tree cover observed in the last 20 years was only possible due to the use of appropriate land sharing/sparing restorative approaches, integrating both socioeconomic and biophysical features of the farm, and have resulted in a heterogeneous tree cover composed of reforests with different capacities to promote biodiversity conservation, ecosystem services provisioning, and local livelihoods. These kinds of restorative interventions were adopted by local stakeholders in 104 cattle farms spanning 2,950 hectares in the La Vieja River watershed (Colombia), as part of the project 'Regional Integrated Silvopastoral Approaches to Ecosystem Management' (Pagiola and Rios, 2013; Rivera et al., 2013).

global restoration targets (Box 1). Land sharing strategies may allow the maintenance of farmland production and conservation of values linked to cultural landscapes at the field and landscape scales; in contrast, sparing would provide all these benefits only at the landscape or regional scales as this restoration approach may occur at the expense of field-level agricultural production (Rey Benayas and Bullock, 2012). Considering both the ecological and social context warrants explicit inclusion in assessments of agricultural and environmental policy (Law and Wilson, 2015). Analysis of the sharing/sparing framework can inform (even not easy) real-world decisions on why, when, where and how implementing which types of FLR interventions. This is essentially an economic framework because it is grounded on the efficient allocation of a competing and usually scarce resource, namely land ("land scarcity"; Fisher et al., 2014). The most critical issue is dealing with land demand where there is no option for deforestation. Countries, organizations, and individuals interested in restoration have been, and continue to be, guided by a suite of tools from which to choose to assess and map restoration potential, identify opportunities, perform cost-benefit analyses, navigate policy, and evaluate social acceptance (Chazdon et al., 2017). We nevertheless emphasize the following guidelines for FLR planning:

- **Consider the spatial distribution and configuration of restorative interventions:** Overarching FLR objectives are highly influenced by the spatial distribution and configuration of tree/forest cover gain, so planning should go beyond estimations of tree/forest cover extents and consider of all land uses in the landscape.
- **Consider social particularities of landscapes:** Selecting one or a bunch of restorative interventions to be implemented is not only about configuration and biophysical conditions. Social context results critical to decide which and where each restorative intervention should be placed. For instance, population is becoming urban in many tropical regions (Seto et al., 2012), and the abandonment of rural areas may be an opportunity for FLR only if they potentially bring some livelihood benefits for people staying in the countryside. The socioeconomic dynamics of landscapes should be considered for selecting land management approaches to decide where and how to promote FLR.
- **Minimize leakage:** Land is becoming scarce due to population growth and higher *per capita* consumption, and there is an increasing global demand for agricultural products (Godfray et al., 2010). Large-scale restoration initiatives, as other land uses, may displace agricultural activities and potentially lead to clearance of native vegetation elsewhere For instance, cropland intensification during the 2000s displaced cattle ranching to the frontier region causing deforestation in Brazil (Barona et al., 2010). Thus, the real risks of leakage have to be incorporated and minimized into FLR planning (Latawiec et al., 2015).
- **Incorporate trade-offs in decision-making:** although FLR aims to achieve more balanced, win-win solutions, trade-offs will be always present (Charpentier, 2015; Brancalion and Chazdon, 2017). Sparing could be a better option for regional biodiversity if the amount of land devoted to conservation represent a suitable area of the landscape. However, at least in tropical countries, sparing could be a worse option for delivering some ecosystem services and improve livelihoods at local scales due to pollution caused by the frequent uncontrolled use of pesticides and fertilizers (Laurance et al., 2014), soil erosion, loss of agro-biodiversity and traditional landscapes (Fisher et al., 2012), and land grabbing for the expansion of industrial monocultures (Grau et al., 2013). Trade-offs and synergies have to be taken into account according to specific program goals, and the view of different stakeholder groups have to be incorporated into decision making in order to build restoration governance.
- **Consider particularities of restorative interventions:** these interventions result in differential outcomes for biodiversity, ecosystem services and local livelihoods (Chazdon et al., 2016), and consequently have different value to spare (e.g., pasture intensification to restore riparian forests) or share (e.g., silvopastoral systems) land in the context of current land uses. Land sharing and sparing may be combined, as for example planning a buffer strips and hedgerow networks that subtract a minimum percentage of farmland to increase forest connectivity and water and nutrient retention (Rey Benayas et al. (2019).

Conclusions

Recognizing that landscapes are dynamic and restoration actually involves permanent and dynamic changes in land use is crucial (Perfecto and Vandermeer, 2012). The simple establishing big numbers related to restoration goals will not convince farmers to set aside land for restoration nor to change their agricultural practices, even more in the absence of the right policies supporting and giving value for restoration. Land sharing and sparing approaches offer interdependent and complementary opportunities to FLR, but the balance between them would depend on the landscape configuration and governance issues to be considered by decision-makers. There is no easy answer regarding the best approach to use, but it is essential to recognize the challenges and opportunities emerging from both land sparing/sharing approaches to promote FLR, involve stakeholders and consider both socioeconomic and biophysical characteristics of a landscape to reduce trade-offs and maximize benefits.

Conflicts of interest

There is no conflict of interest for any author.

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