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PROFILE

Sustainable Cattle Ranching in Practice: Moving from Theory to Planning in Colombia's Livestock Sector

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Abstract A growing population with increasing consumption of milk and dairy require more agricultural output in the coming years, which potentially competes with forests and other natural habitats. This issue is particularly salient in the tropics, where deforestation has traditionally generated cattle pastures and other commodity crops such as corn and soy. The purpose of this article is to review the concepts and discussion associated with reconciling food production and conservation, and in particular with regards to cattle production, including the concepts of land-sparing and land-sharing. We then present these concepts in the specific context of Colombia, where there are efforts to increase both cattle production and protect tropical forests, in order to discuss the potential for landscape planning for sustainable cattle production. We outline a national planning approach, which includes disaggregating the diverse cattle sector and production types, identifying biophysical, and economic opportunities and barriers for sustainable intensification in cattle ranching, and analyzing areas suitable for habitat restoration and conservation, in order to plan for both land-sparing and land-sharing strategies. This approach can be used in other contexts across the world where there is a need to incorporate cattle production into national goals for carbon sequestration and habitat restoration and conservation.

Keywords Sustainable intensification · land-sparing · land-sharing · silvo-pastoral systems · tropical cattle ranching

Introduction

Despite falling fertility rates worldwide, population momentum and the growing demands of middle-class diets mean that food demands will continue to increase into the future (Godfray et al. 2010). In particular, a growing urban population means that demands for livestock products (milk and meat) will double by 2050 (Herrero et al. 2009; Thornton 2010). Livestock production, and particularly cattle, represents 30% of agricultural land-area through direct pasture use and feed crops (Herrero et al. 2013). Additionally, it contributes 10 to 18% of global greenhouse gas (GHG) emissions, with beef and milk production accounting for around half of total livestock emissions (Gerber et al. 2013; Steinfeld et al. 2006).

Recently there has been increased interest in the "sustainable intensification" of cattle production both on the ground at the farm scale and also in terms of creating public policy that encourages sustainable livestock production, particularly in the tropics where there is the risk of forest

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loss that would impact the global carbon balance (Godfray et al. 2010; Tilman et al. 2011; Garnett et al. 2013; Cohn et al. 2014; Rudel et al. 2015). Although there are localized cases of increasing livestock production in a way that fosters ecosystem services (for example, intensive silvopastoral systems (Murgueitio et al. 2011), or potentially encouraging cattle intensification and therefore saving the need to expand pasture lands into tropical forest (Cohn et al. 2014)), there is still a need to direct policy and planning at a national or regional scale that would reconcile the goals of intensifying livestock production while fostering ecosystem services and protecting or restoring native lands.

Given the global momentum in climate policy (Paris Accords) and sustainable development (the UN's Sustainable Development Goals), sustainable cattle ranching is a timely and important topic, particularly in the tropics where native habitat and tropical forest are at risk given potential cattle pasture expansion. This paper provides an overview of concepts and approaches that attempt to reconcile the conservation-agricultural production dilemma, such land-sparing and land-sharing, and the way that these concepts can be operationalized in national landscape planning, using the case of Colombia, where there is interest from many sectors to intensify cattle production while restoring and/or conserving native ecosystems. By examining a variety of analytical instruments and approaches, we discuss how a tropical country such as Colombia can develop a National Sustainable Cattle Plan, and what lessons from its process can be applied to other countries and contexts. A successful Cattle Plan must disaggregate the diverse cattle sector and target particular policies to specific regions and groups to foster ecosystem services, including carbon storage, increase productivity, and restore degraded lands. At the same time, cattle production planning must be integrated into conservation and restoration goals to achieve national targets for productivity, rural development, and environmental sustainability.

Definitions and Concepts

Sustainable Intensification

There is global dialog which is confronting the dilemma of increasing food production without destroying the environment by focusing on "sustainable intensification", or increasing productivity in a sustainable way (Foley et al. 2011). According to the Montpellier Panel, sustainable intensification "is about producing more outputs with more efficient use of all inputs—on a durable basis—while reducing environmental damage and building resilience, natural capital and the flow of environmental services" (The Montpellier Panel 2013). This means there are two aspects that are intensifying: Actual output, or yield per unit land area, and also ecosystem services, which means increasing environmental benefits per unit land area. The idea of sustainable intensification can get interpreted in two different yet potentially complementary ways: through land-sparing or the idea of intensifying productivity in one place while conserving another, or through land-sharing or wildlife-friendly farming, where agriculture itself promotes ecosystem services and therefore is intensifying the ecological and productivity gains in one landscape (Grau et al. 2013).

Land-Sparing

The concept of land-sparing has been advocated by Phalan and Green, amongst others, although the concept has persisted for some time through the Borlaug Hypothesis and the idea that the Green Revolution spared land from being deforested for agriculture (Angelsen and Kaimowitz 2001; Green et al. 2005; Phalan et al. 2011b). The theory is that by intensifying production in one area through higher yields, land is freed up to conserve in another. This discussion is based on the analysis that in any modified landscape for agriculture, biodiversity suffers, even in low-yielding agricultural areas (Phalan et al. 2011b).

There are several complexities for the land-sparing theory to function successfully in the case of tropical cattle ranching. First, land-sparing can potentially lead to increased forest clearing through making cattle production more profitable, for example, and therefore cause expansion (Kaimowitz and Angelsen 2008). At the same time, increasing the production of commodities can lead to depressed prices which may or may not cause consumers to increase demands, which could again lead to agricultural expansion, or "leakage" effects (Kaimowitz and Angelsen 2008; Cohn et al. 2014). Additionally, and important for the case of tropical countries, one of the factors causing low productivity and therefore extensive cattle ranching is the lack of access to capacity, technological information, and the inputs needed to increase productivity, requiring the investment in transport systems such as roads. However, investing in infrastructure and improving roads is also a stimulant for native ecosystem and particularly forest conversion, which therefore backfires in terms of habitat conservation (Angelsen 2010). This issue gives greater cause to comprehensive national planning for cattle production that would include instruments that protect particular habitats and prevent deforestation, while encouraging habitat restoration.

Land-Sharing or Wildlife-Friendly Farming

In addition to land-sparing, other scholars advocate for land-sharing, also known as wildlife-friendly farming (Tscharntke et al. 2012) or multi-functional agriculture

(Renting et al. 2008). This approach claims that ecosystem services can be fostered *within* agricultural landscapes, or combining uses within a production system. One of the assumptions in the dichotomy between land-sparing and land-sharing/wildlife-friendly farming is the implicit idea that the latter will produce less food than the former. In other words, farmers can either increase yields in an environmentally destructive way or produce lower yields but have a greater generation of ecosystem services. However, there are examples where land-sharing techniques can also increase productivity, as in the example of intensive silvopastoral systems for cattle ranching, which will be discussed below.

First, it is worth noting that advocates for land-sharing approaches demonstrate that particularly smallholder agriculture can foster biodiversity and habitat conservation through a "landscape" or "agroecological matrix" (Perfecto and Vandermeer 2010; Tscharntke et al. 2012) which causes a higher agro-ecological potential and provision of ecosystem services in general. Land-sharing approaches do not discount the need for conservation of native landscapes, however they also advocate the importance of community-based management of natural resources (ibid). This is particularly the case in the tropics, where smallholder agriculture dominates the landscape and often provides a diversity of wildlife habitat (Perfecto and Vandermeer 2010; von Wehrden et al. 2014). Indeed, even individual trees within agricultural landscapes have been found to greatly increase the presence and diversity of bats and birds (Fischer et al. 2010). McGroddy et al. showed that even in spontaneous silvopastoral systems where land-owners allowed trees to grow in their pasture, the above-ground carbon values can potentially be as high as managed agroforestry systems and secondary forest (McGroddy et al. 2015).

Integrated Approaches for Tropical Livestock Production

The consistent question that emerges from this debate is how to balance food production with ecosystem service generation, or generate "win-win" solutions (Angelsen and Kaimowitz 2001). A win-win approach would encourage land-sparing and conservation in addition to land-sharing, depending on the local and national context (Grau et al. 2013; Fischer et al. 2014). Indeed, Brazil has successfully encouraged forest conservation alongside livestock intensification, which has reduced annual deforestation by 75 % from 2004 to 2014 while increasing productivity of cattle (Nepstad et al. 2014). While this is a land-sparing vision, they could also create policies to encourage localized land-sharing approaches where the landscape lends itself to more "fine-scale" approaches (Fischer et al. 2008).

In the case of many tropical countries, strategies for livestock production exist that potentially lower carbon emissions and are yield-increasing, which can reconcile the land-sparing and land-sharing debate. One such example is improved forage systems that incorporate several species of grasses and legumes, which provide a more nutritious diet (Rudel et al. 2015). The improvement of diets can go a long way in increasing productivity and reducing greenhouse gas emissions from livestock operations. Improved forages are particularly important for tropical livestock systems, which often face difficult biophysical conditions such as low soil fertility and varied seasonal rainfall, which produces either drought or rainfall extremes and leads to pest outbreaks (Rao et al. 2015). Biophysical conditions combined with economic challenges such as the lack of infrastructure and government programs have led to the underdevelopment of livestock production in many tropical countries (ibid). Improved forage systems which combine the breeding of improved grasses ("genetic improvement") with leguminous forages, trees, and crops have been shown to increase productivity, lower GHG emissions per unit of output, and improve the livelihoods of producers (Herrero et al. 2010; Rudel et al. 2015).

An even more integrated approach for sustainable intensification of livestock is the implementation of silvopastoral systems, which range from less to more intensive. Silvopastoral systems are grassland grazing systems that also include trees and shrubs that form a multi-story forage landscape. They range from less intensive systems including dispersed trees to intensive silvopastoral systems which contain herbs, high density of fodder shrubs (>10,000 ha^{-1}), and trees, often leguminous, which provide high nutrient fodder, shade, biodiversity habitat, carbon sequestration, and the fixation of nitrogen (Murgueitio et al. 2011; Broom et al. 2013). Other elements of these systems include forage banks where forage is cut and carried for animal consumption, the introduction of nutritious forages that reduce the need for grain-based feed, and the use of live fences which delineate paddocks and provide timber. Silvopastoral systems call into question the incompatibility of pasture and trees, which has long been engrained into the tropical cattle ranching community and has caused the elimination of tree-cover in the name of productive and extensive cattle pasture (Calle et al. 2013).

Silvopastoral systems are popular within the agenda for sustainable cattle intensification in the tropics and particularly in Latin America. Results in pilot studies in Colombia show that the implementation of silvopastoral systems can increase meat and milk production more than seven and three times, respectively (from 200 to 1500 kg/ha/year and 800 to 3000 L/ha/year (Murgueitio et al. 2011)). In a project for small-scale producers, forage banks were planted in farms that range from two to five hectares in the Colombian

Andes and milk production increased by 300–400% (Murgueitio et al. 2006). The applicability of these systems can be applied to small-scale producers particularly because of the diversity of technologies: even with forage banks and live fences, which cost half of more intensive systems, the carrying capacity of a farm can increase by 250% (Murgueitio et al. 2006).

The examples of these improved livestock systems demonstrate how the definition of "intensive" is not just increased production per unit area, but also the increase of ecosystem services provision on the same land. In the end, both land-sharing and sparing need to be incorporated into a sustainable cattle planning, as has been discussed by several scholars (Fischer et al. 2008; Tscharntke et al. 2012; Grau et al. 2013). Despite the potential benefits of intensive agricultural and livestock production, often it is not enough for conservation and biodiversity goals. The example of oil palm in Peru demonstrates that intensification needs to be balanced with both on-farm conservation strategies and protected areas (Gutiérrez-Vélez et al. 2011). In the case of cattle ranching in many parts of the tropics, the landscape is quite heterogenous, meaning there is no one policy or plan to encourage sustainable intensification. As Fischer et al. (2008) note, heterogeneous, patchy landscapes can encourage wildlife-friendly farming while "course-grained", large-scale production could be more oriented towards land-sparing while integrating land-sharing approaches and protected areas. In the case of cattle in Colombia, the sector contains both landscape types. Therefore, a national vision must define where and how to balance the production-conservation spectrum.

In summary, the need exists to conserve wild natural areas, both native and restored, and to increase the ecological value of livestock production landscapes. This is underscored by The Nature Conservancy's evolution of their stated priorities, moving from only protecting wild landscapes to also having an integrated plan for wildlife-friendly farming. It is true that biodiversity is highest in tropical forests and native ecosystems compared with any type of agricultural landscape (Phalan et al. 2011a). But at the same time, it is possible to increase productivity while also fostering ecosystem services, which is necessary for increased food production without expanding into new areas.

National Visioning for Sustainable Cattle Ranching: The Case of Colombia

Given the variety of approaches along the conservation-production spectrum, it is helpful to understand how they can be employed in a real-world example. Colombia is a case that is currently strategizing how to incorporate several strategies into national planning, so it can also serve as an example to other tropical countries that are moving in that direction, particularly in Latin America. As will be discussed below, one of the most important aspects of sustainable landscape planning for cattle production is the need to disaggregate the country in similar regions and production types to encourage both intensification and biodiversity conservation.

Like many other Latin American countries, Colombia encompasses a heterogeneous landscape that includes a variety of cattle production strategies across its diverse settings. Cattle production has long been part of Colombia's economic sector and consequently its landscape, including in inter-Andean valleys, dry and humid tropical savannahs, and coastal plains. Throughout the 19th and 20th centuries, vast amounts of native forest were cleared in order to plant pastures for cattle grazing, both for productive ventures and to control territory (Van Ausdal 2009). As of 2011, approximately 1.6% of the GDP of Colombia came from cattle production, which is 20% of agriculture's contribution (coffee is just shy of 6%) (Fedegan 2012). Over a third of the country's land area is covered by pastures for cattle grazing, with an average of 0.60 animals per hectare, exemplifying the extensive and low-productive nature of Colombian livestock systems which is typical of the tropics (Fedegan 2012; Calle et al. 2013; Fig. 1). Eighty-one percent of cattle farms have less than 50 head of cattle, and they are found across the mountains, valleys, and savannahs throughout the country (ibid; Table 1).

Because of the diversity of cattle production systems and environments, the ubiquitous livestock production in Colombia is one of the major drivers of ecosystem transformation. Indeed, estimates claim that up to 45% of native systems were transformed by the end of the 20th century and between 2005–2010, 56% of deforestation nationwide resulted in cattle pastures (Etter et al. 2006; Murcia and Guariguata 2014; Vanegas Pinzon et al. 2015). According to the Ministry of Environment and Sustainable Development, 23% of the national landscape is degraded and in need of restoration (Vanegas Pinzon et al. 2015). Additionally, early estimates of greenhouse gas emissions demonstrate that 38% of the country's emissions come from agriculture, with half of those from livestock production (IDEAM 2010).

Given the need for production, conservation, and restoration, several important actors in the country have recently pledged to reduce the impacts of cattle. The national cattle ranching association, Fedegan, states in its strategic plan for 2019 that they hope to double the national herd to 48 million while reducing the area dedicated to livestock by 10 million hectares (Fedegan 2006). The country has been pursuing a Low-Carbon Development Plan (ECDBC) since 2012, which establishes baseline emission scenarios and alternative development pathways in

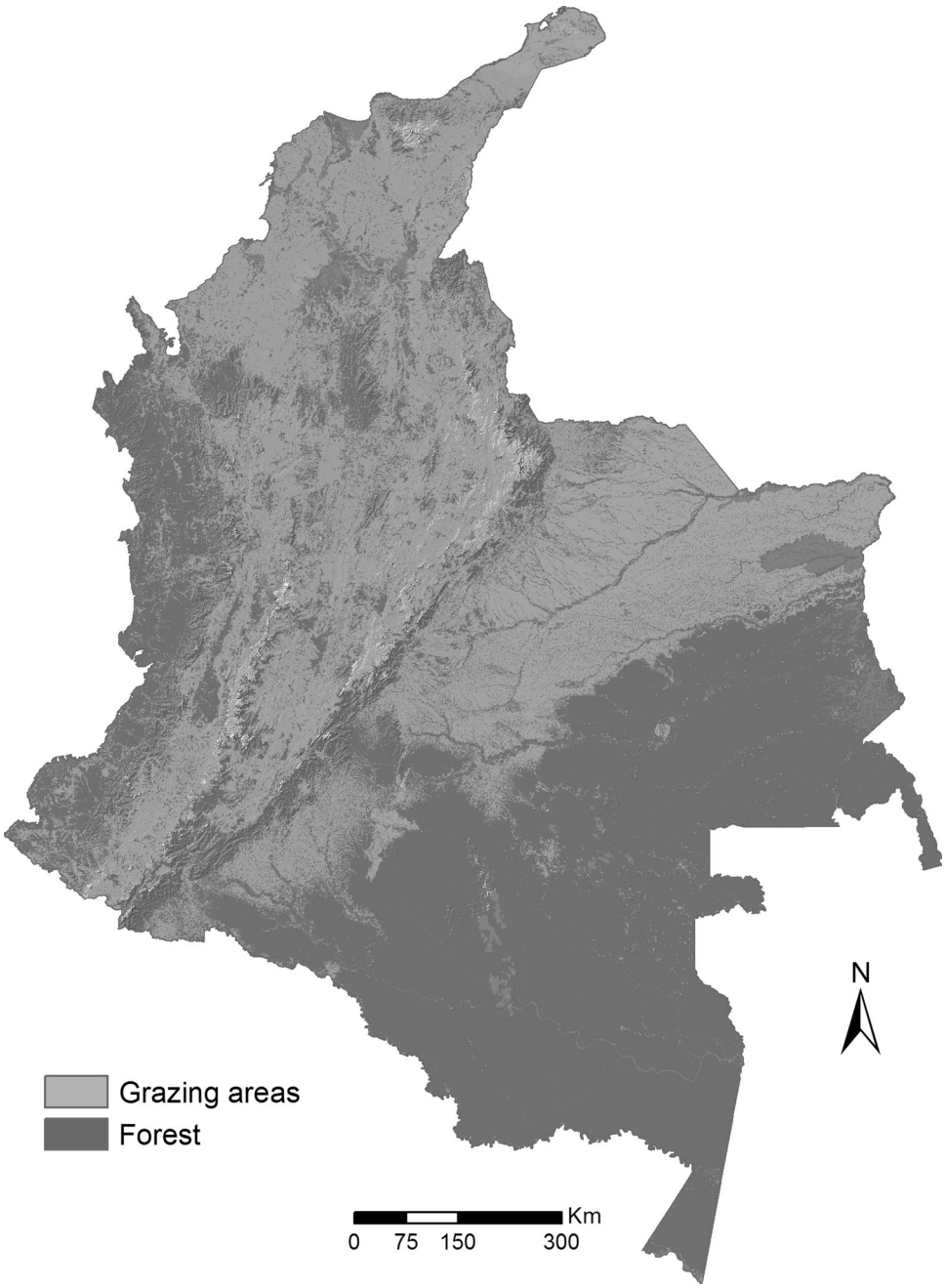

Fig. 1 Land-cover in forest and pastures across Colombia. Elaborated by A. Zuluaga

Table 1 Percentage of farms in Colombia according to number of cattle per farm (Fedegan 2015)

Cattle inventory (animals)	<10	11–25	26–50	51–100	101–250	251–500	501–1000	>1000
Farms (%)	43.7	23.0	14.2	9.5	6.4	2.1	0.8	0.3

the diverse sectors of the economy, and constructs National Appropriate Mitigation Action Plans (NAMAs), and Monitoring, Reporting and Verification (MRV) systems (MADS 2012). The strategies outlined by the ECDBC were incorporated into the national development plan 2014–2018 constructed by the National Planning Department (DNP 2015). The national government is also designing other public policy instruments (i.e., National Political, Economic, and Social Advisory Documents (CONPES)) that encourage the scaling of sustainable livestock practices, and specifically designing Payment for Ecosystem Services schemes which are in a preliminary phase of design and public consultation. Most recently, the national government pledged in 2014 as part of the Initiative 20 × 20 to restore

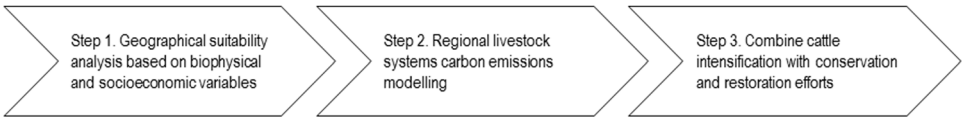

Fig. 2 Steps for national cattle planning

one million hectares of land throughout the country (WRI 2015) and to reduce GHG emissions by 20% in 2030 in relation to a BAU scenario (Gobierno de Colombia 2016).

Fortunately, there are several research initiatives across the country in universities and research institutes that have focused on sustainable livestock practices in Colombia (and similar tropical areas), including within the national agricultural research institute, Corpoica. One specific example is the leadership of the Center for Research on Sustainable Agricultural Systems (CIPAV), which has worked on silvopastoral systems on an experimental farm for 30 years. The success of pilot farms and projects has led to a larger-scale, national project called the Mainstreaming Biodiversity into Sustainable Cattle Ranching (MBSCR) Project within the National Cattle Association, which implements silvopastoral systems and payments for ecosystem services in five regions of the country, across 3500 cattle ranches (Fedegan 2016)[1]. Simultaneously, the International Center for Tropical Agriculture (CIAT) has been dedicated towards improving tropical forages for livestock, in Colombia and elsewhere in the tropics (Peters et al. 2013).

Approaches for National Planning

Despite the goals and promises that have been set forth nationally in Colombia, there is still no specific national strategy of how to attain them. This is where land-sparing and land-sharing concepts can assist in the national visioning for a Sustainable Cattle Plan. Such a plan requires what has been called an "integrated landscape approach" (Chazdon et al. 2009) or "whole-landscape approach" (DeFries and Rosenzweig 2010) that would incorporate national landscape planning, which identifies biophysical and economic constraints, and integrates ecological restoration, conservation of ecologically sensitive habitat such as tropical forests (land-sparing approaches), and emissions reduction targets that are encouraged through sustainable cattle production methods (land-sharing approaches). The landscape planning then needs to be paired with public policy instruments that can encourage and facilitate such transformation.

In order to create such an approach, several steps are needed (Fig. 2). First, there needs to be an in-depth suitability analysis for the best areas for livestock intensification, ecological restoration, and habitat conservation, based on both biophysical and economic variables. Biophysical constraints include land that is not fit for livestock production because of slope, soil fertility, climate, or other important factors. Additionally, biophysical constraints encompass areas that are ecologically sensitive, and in the case of Colombia would include landscapes such as wetlands, protected areas, and areas with high levels of endemism. At the same time, in areas where there are conflicts between cattle grazing and ecological sensitivity, it is necessary to take into account cattle productivity as a key element to define which areas are really suitable for grazing. Other factors to be considered in determining the best areas for livestock intensification or ecological restoration include the level of pasture degradation and forage potential (areas with degraded pastures and low forage potential should not be priority livestock intensification areas) (Angelsen and Kaimowitz 2001).

Socio-economic constraints are more challenging to visualize geographically but very important for national rural development goals (FAO 2016). They would include variables such as the percentage that cattle ranching makes up of the local agricultural GDP, poverty rates, education levels, access to infrastructure such as drainage and electricity, and also the cost of transporting both inputs and goods produced such as meat and milk (Herrero et al. 2014). Understanding the socio-economic characteristics of different cattle production systems is particularly important for the creation of policy and planning instruments. Indeed, identifying different groups of producers with varying assets and capital is imperative in order to propose effective incentives that encourage intensification (Angelsen and Kaimowitz 2001).

Second, carbon emissions modeling can be integrated to establish targets of overall land areas that could be managed in different ways for livestock production, and the implications for carbon emissions. For example, what are the production and emissions implications of a certain percentage of land-area in silvopastoral systems or in more extensive systems? Combinations of in situ data from field measurements and cattle emissions modeling based on diet can assist in setting targets that are consistent with national goals, and are necessary for reaching target emissions levels (Herrero et al. 2013; de Moraes Sa et al. 2017).

[1] The MBSCR project is funded by the Global Environment Facility and the Departament of Business, Energy and Industrial Strategy of Great Britain, and coordinated by the World Bank. The Government of Colombia manages the project and the cattle association, Fedegan, leads the project, with technical assistance from The Nature Conservancy, CIPAV, and Fondo Acción, a Colombian NGO.

Third, cattle intensification must be paired with conservation and restoration, so that ecologically sensitive are conserved or restored, while encouraging higher productivity in appropriate regions. Brazil has embraced this approach with its "ABC" plan which integrates both low-emission and higher productivity livestock production with degraded pasture restoration (de Moraes Sa et al. 2017). This integrated plan includes the implementation of crop-livestock-forest systems, nitrogen fixation through plants instead of chemical fertilizers, the restoration of degraded pastures, and the growth of forest plantations on land previously used for agriculture. These strategies, paired with reduced deforestation in the Amazon by extensive government monitoring, "black-listing" municipalities who have high rates of deforestation, enforcing deforestation laws, and intervening in the soy and cattle supply chains through agreements not to buy products that come from deforested areas, have reduced deforestation by 75% from 2004 to 2014 (Nepstad et al. 2014).

Once the appropriate strategies for Colombia have been identified, a coordinated government effort is necessary to create target reductions and plans to implement shifts in agriculture. In the case of Colombia, there are particular opportunities and constraints that exist for a coordinated effort. In terms of opportunities, Colombia is poised to propose mitigation targets and strategies to move forward with shifts in the livestock sector, with support from many sectors and branches of government. Although Colombia cattle production is not geared towards export markets (which, in-part, pressured Brazil to take action), there is willingness and interest in the sector and in the national government to make cattle production more competitive internationally and with a certification of sustainable production. Additionally, and as previously mentioned, the Colombian government has promised to reduce emissions and increase reforestation, which can only be accomplished by integrating sustainable livestock production.

There are several significant barriers to implementing improved livestock ranching practices, including the cost of initial implementation, the capacity and knowledge of producers to modify their practices, and the creation of sustainable certification schemes and markets for products. As seen in Table 1, the bulk of cattle in Colombia exist on small farms, which tend to have low levels of technology and capacity for cattle intensification. A Sustainable Cattle Plan would need to address these barriers by a coordinated effort which incorporates several sectors. First, there are several government programs through the Ministry of Agriculture and Rural Development that could provide capacity and financial assistance, through the land titling program (currently being reformed and implemented), which will assist in productive activities, and the Incentive for Rural Capitalization Program, which provides paybacks for investments in silvopastoral production (MADR 2013). The creation of NAMAs in both the forestry and livestock sectors are gaining approval from the Environment and the Agriculture Ministries, which propose GHG emission targets only attainable through integrated planning for sustainable cattle production. Several actors and institutions are poised to contribute their expertise to improving the issue, including Fedegan.

Additionally, opportunities exist to improve existing chains of capacity building, which have traditionally been focused on exclusively Green Revolution technologies. For example, the National Learning Service (SENA), a public institution which offers training and educational programs (as part of the Ministry of Labor), could offer programs specifically on silvopastoral systems and improved forage approaches. The National Department of Science, Technology, and Innovation could offer funding initiatives for research dedicated to understanding biophysical and economic barriers for sustainable livestock production strategies, as well as measuring the impact of implementing these strategies. Although certification schemes are being considered, there are still questions of the viability of sustainable cattle products that might imply a higher price to consumers since most of the milk and meat produced in Colombia is for national markets. Financial instruments must take price into account for national markets, and also look into international markets to provide consumers who can pay the price.

Overall, there is currently an opportunity for Colombia to take advantage of interest across sectors and institutions to create an integrated Sustainable Cattle Plan, which would include forest protection and habitat restoration. An integrated plan needs to both protect natural areas through land-sparing approaches intensified production (at a regional and national scale) and also foster wildlife diversity and carbon sequestration within and across productive landscapes at a local scale. Thus, it requires integration of different sectors of government and a variety of scales so that productivity, forest cover, and biodiversity simultaneously increase.

At the same time, successful planning for sustainable cattle ranching needs to include the participation of several sectors, including local producers and communities, through multi-stakeholder planning at various scales (Scherr et al. 2012). This kind of integrated and multi-scalar vision could serve as an example for countries throughout the tropics to encourage sustainable intensification, optimizing productivity and the generation of ecosystem services. Although it requires the scaling-up of successful, locally implemented approaches, a whole-landscape approach that combines wildlife-friendly farming and land-sparing approaches could prove successful in the Colombian context, which could then be exported to other tropical countries throughout the world.

Conclusions and Lessons-Learned

It is time for the concepts related to sustainable intensification to be transformed into effective planning and policy. This paper takes the conceptual approaches for reconciling conservation and food production and offers strategies to develop a national Sustainable Cattle Plan using the case of Colombia. Although our discussion is focused on one country, the approaches for establishing where and how to facilitate both land-sparing and sharing approaches could apply to many tropical countries across the globe. These approaches start with disaggregating the cattle sector regionally and by production type, defining the most important areas for conservation, and understanding geographical biophysical limitations and opportunities for particular production strategies. It also requires coordinating across government sectors, including environmental sectors, agricultural sectors, and education and capacity-building sectors. The efforts to encourage more sustainable cattle production strategies can be linked to international financial mechanisms and to national goals for restoration and carbon mitigation.

In the case of Colombia, several international and national initiatives have placed the country in an ideal position to create integrated plans for sustainable cattle intensification, which would include land-sharing initiatives (i.e., silvopastoral systems) and conserving and restoring land. The idea of a Sustainable Cattle Plan is actually at the heart of a national planning in Colombia, because of the scale and impact of the sector. The approaches outlined here to design effective planning for sustainable cattle production could potentially assist other countries in similar positions, given the goals outlined in international agreements for carbon sequestration and habitat restoration and/or conservation. They include technical analyses, government coordination, and scaling of local initiatives to national instruments that encourage sustainable production techniques. Despite being one of the drivers of habitat loss, tropical cattle production can potentially become a source of climate mitigation and ecosystem services in Colombia and across the globe.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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