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ARTICLE

Regenerative cattle farming in Latin America and the Caribbean, far beyond the oxymoron

Pecuária bovina regenerativa na América Latina e no Caribe, muito além do oximoro

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Abstract: Latin America and the Caribbean offer the most favorable natural and social conditions for the emergence of livestock farming that regenerates and maintains the ecosystem services on which life depends, is energy efficient and contributes to meeting fundamental human food needs. The region accounts for 44% of global beef exports. As demand for beef is unlikely to grow explosively, the adoption of regenerative methods of cattle farming, which aim to minimize environmental destruction and methane emissions, is becoming increasingly urgent. The concept of regenerative beef farming may be viable and is based on three main dimensions: animal welfare, improved biodiversity and human health. The region is particularly characterized by pasture-based cattle farming and is predominantly carried out on family farms. Moderate intensification can promote innovation, reduce the area occupied by livestock farming and mitigate its socio-environmental impacts, promoting a more sustainable model of beef production.

Keywords: animal welfare, deforestation, moderate intensification, pastures, cattle farming.

Resumo: A América Latina e o Caribe oferecem as condições naturais e sociais mais favoráveis para o surgimento de uma pecuária que regenere e mantenha os serviços ecossistêmicos dos quais a vida depende, que seja eficiente em termos de energia e que contribua para atender às necessidades alimentares humanas fundamentais. A região representa 44% das exportações globais de carne bovina. Como é improvável que a demanda por carne cresça de forma explosiva, está se tornando cada vez mais urgente a adoção de métodos regenerativos de criação de bovinos, que visam minimizar a destruição ambiental e as emissões de metano. O conceito de pecuária bovina regenerativa pode ser viável e se baseia em três dimensões principais: bem-estar animal, melhoria da biodiversidade e saúde humana. A região é particularmente caracterizada pela pecuária bovina a pasto e é predominantemente realizada em propriedades familiares. A intensificação moderada pode promover a inovação, reduzir a área ocupada pela pecuária e mitigar seus impactos socioambientais, promovendo um modelo mais sustentável de produção de carne bovina.

Palavras-chave: bem-estar animal, desmatamento, intensificação moderada, pastagens, pecuária bovina.

1. Introduction

The food guides for Brazil (Monteiro et al., 2015), Mexico (Rivera et al., 2024), Peru (Serrano & Curi, 2019) and Colombia (Instituto Colombiano de Bienestar Familiar, 2020) converge in two fundamental directions: the urgency of reversing the advance in the consumption of ultra-processed products and the need to reduce the consumption of foods of animal origin (Kovalskys et al., 2019). It is not a matter of advocating veganism or vegetarianism, but of promoting the diversification of diets, increasing the consumption of vegetables, fruit, legumes

and whole grains, which paves the way for a diet less dependent on the consumption of animal products (Camargo et al., 2023). Of the five largest global beef consumers per capita, two (Argentina and Brazil) are in Latin America (Organisation for Economic Co-operation and Development, 2023). The FAO report predicts (Food and Agriculture Organization, 2023) that over the next two or three decades there will be a much smaller increase in demand, especially for beef products, than that projected, for example, by the World Economic Forum (2020), which predicts an 88% increase in global demand for meat by 2050. In Latin America and the Caribbean (Food and Agriculture Organization, 2023) per capita demand for milk is expected to remain stable until 2050, and for beef the estimate is for an increase in per capita demand of just 0.7%. It is only in sub-Saharan Africa that there will be a significant increase in demand for beef per capita. But since the starting point for consumption is low and since the main research organizations are committed to increasing the region's food sovereignty by strengthening crops adapted to its ecosystem conditions (Thilsted & Elouafi, 2023; Singh et al., 2022; Krug et al., 2023; Köberle et al., 2023; Matte et al., 2024), the explosion in demand for animal proteins that is so much talked about is increasingly distant from what the most balanced forecasts (Baxter & Garnett, 2022) point to.

If the demand for meat is not explosive, this means that it becomes even more urgent (and, above all, possible) to adopt regenerative methods of cattle farming, both in terms of deforestation and the methane emissions that are organically inherent in their husbandry. This article, based on a series of interviews with entrepreneurs and researchers in the sector and an extensive review of the literature, seeks to combat the idea that the expression "regenerative cattle farming" can only be considered an oxymoron. On the contrary, even in regions where livestock is currently associated with the large-scale destruction of ecosystem services, there are methods that allow the supply of their products on the basis of moderate intensification and the low opportunity cost of feeding livestock.

There are three basic dimensions to the definition of regenerative cattle farming. The first dimension refers to animal welfare, which is achieved when animals can graze freely. The second dimension involves the contribution to improving biodiversity and carbon storage that well-managed soil and healthy pastures can make. The third dimension is human health, which mainly involves what the International Labor Organization calls decent work, as well as the quality of the products provided by cattle farming.

Latin America and the Caribbean account for 24% of the world's cattle herd (Congio et al., 2021). With 13.5% of the world's population, the region is responsible for 23% of the world's beef supply and 11.8% of milk production (Food and Agriculture Organization, 2021). Brazil has the largest commercial herd in the world, with more than 224 million cattle heads, and is the world's largest meat exporter.

Both the size of the meatpacking plants and the size and social nature of the large cattle farms hide a fundamental characteristic of Latin American and Caribbean livestock: a very important part of cattle farming (especially that known as "cria", which corresponds to the first eight months from the animal's birth and is the most demanding in terms of human labor and the greatest risk of losses) is under the control of family farmers. At this early stage, livestock is less concentrated than in the final stages of husbandry, just before slaughter (Matte & Waquil, 2020, 2021). Given the dispersal of the activity in units with a few dozen animals, it is also the phase in which it is most difficult to trace the animals and in which a significant part of the deforestation is concentrated.

In Peru, 88% of cattle are kept on farms of less than 10 hectares (Food and Agriculture Organization, 2023). In Brazil, 2.5 million farms are dedicated to cattle farming, 75% of

which are family-run (Food and Agriculture Organization, 2021). In Colombia, 81% of the 623,000 establishments with cattle have fewer than 50 animals each (Deutsche Gesellschaft für Internationale Zusammenarbeit, 2020). In Central America, around 86% of cattle farms are smaller than 18 hectares and house between four and twenty animals, with an average load of 1.5 animal units per hectare (AU/ha).

Cattle fulfill different functions for family farmers and ranchers. In many circumstances, especially when access to markets and banking organizations is difficult, cattle often serves as the basis of family savings, and its liquidity (greater than that of other assets controlled by farmers) allows it to be sold quickly in emergency situations (Food and Agriculture Organization, 2014; Waquil et al., 2016; Matte et al., 2019; Matte & Waquil, 2020). Family farms predominate in milk production, as the entire production cycle is labor intensive (Thies et al., 2023). The marketing and industrialization of milk and its derivatives generally depend on cooperative organizations, and the entire dairy chain is a major generator of jobs.

The most important characteristic of dairy farming in Latin America and the Caribbean is that it is fundamentally based on pasture (Carvalho, Batello, 2009; Greenwood, 2021; Fernández et al., 2020; Modernel et al., 2019; Alexandre et al., 2021). While in the United States and Europe 70% and 65% of cattle are confined, respectively, in Latin America and the Caribbean the percentage is much lower. In the Brazilian cattle herd, confinement is limited to the final stage of husbandry and, in 2021, reached only 15.6% of the animals (Froehlich et al., 2022). It is in this predominant characteristic that both the strength and the main problems of cattle farming in Latin America and the Caribbean lie.

The second part of the article discusses the ecosystem functions of native pastures and the social benefits of feeding cattle with plants that don't compete with human needs. It recognizes that most cattle farming in the region is based on the destruction of the forest. At the same time, it demonstrates the potential of moderate intensification to eliminate the link between cattle farming and deforestation. The third item presents the idea of moderate intensification as an accessible and low-cost way to promote innovations that can reduce the area occupied by cattle, increasing productivity, reducing emissions, and regenerating biodiversity.

2. Moderate intensification and low opportunity cost

An important part of the Latin American and Caribbean cattle herd occupies areas of native pasture. These areas have been occupied by large herbivores since the beginning of the Holocene. The ecosystem services provided by these territories and the relationships between the soils, their microbiota and the plants that grow in them depend on the grazing activities of large animals (Matte & Waquil, 2020; Baggio et al., 2021; Manzano et al., 2023a). The native pastures of the continent, such as those of the Pampa, Pantanal, Páramos, Caatinga, the Patagonian steppes or the Guiana savanna, but also those located in the Amazon itself (Townsend et al., 2012), are the most important Latin American and Caribbean examples of these ecosystems, which have two fundamental advantages for the agri-food system.

Firstly, the digestive system of ruminants, unlike monogastric animals, allows them to obtain energy and nutrients contained in the cell walls of plants, in the form of fibers. It is true that the rate at which ruminants convert calories and plant proteins into products that can be consumed by humans is much lower than that of monogastric animals (Monbiot, 2022; Godfray et al., 2018), i.e. ruminants need more energy (in the form of plants) for every unit of energy in the form of meat that they offer. However, the calculation of energy efficiency in the transformation of plant products into animals needs to take into account that humans do not

have direct access to the nutrients that make up the food of grazing cattle (Berners Lee et al., 2018). In other words, pasture-raised cattle compete significantly less with human food than monogastric animals, whose diet is fundamentally based on animal food made predominantly from grains (Manzano et al., 2023a).

Globally, Cheng et al. (2022) found that monogastric animals husbandry (most of which are fed products that could be used directly in human food) requires four times more productive area than ruminants per unit of protein. The growing increase in poultry and pig farming has contributed to the increase in grain production, which, despite the increase in productivity, is expanding territorially, compromising the biodiversity of the areas over which it advances (Herrero et al., 2023a, 2023b).

The work of Mottet et al. (2017) shows that 86% of ruminant food worldwide cannot be digested by humans. As this is a global average, and therefore includes those livestock that are stabled and highly dependent on grain, the share of ruminant food that does not compete with human food in Latin America and the Caribbean may be even higher. In addition, cattle can receive nutrients from brewery waste, citrus pulp, cottonseed, and alcohol distillery waste, thus offering a strong opportunity to act as a recycling element within a circular economy.

In short, cattle farming on native pastures and, in the case of tropical forests, with moderate intensification technologies marked by plant diversity, the introduction of legumes and tree plantings in the landscape, as in the Guaxupé method, results in what van Zanten et al. (2023) call the low opportunity cost of animal husbandry. This is because the Guaxupé System, proposed by Embrapa, makes it possible to intensify livestock farming with less economic investment and benefits for the environment (Andrade et al., 2023a).

In addition to this advantage, the supply of cattle products on native pastures based on these moderate forms of intensification strengthens fundamental ecosystem services, both in terms of biodiversity and their ability to sequester greenhouse gases and store carbon in the soil. Even more, these services would hardly be provided if these areas were no longer used for cattle farming (Leroy et al., 2022). The biodiversity of natural pasture soils is impressive. The native pastures of the Pampa biome, found in southern Brazil, Uruguay, Argentina and Paraguay, are made up of around 450 species of forage grasses and more than 150 species of legumes (Boldrini, 1997) and other families. There are a total of 3,642 species in this region alone (Andrade et al., 2023b). In native pasture areas in the south of the continent, emissions from cattle farming are reasonably neutralized when managed properly (Cezimbra et al., 2021; Damian et al., 2023). The link between the Alianza del Pastizal (which brings together cattle farmers from the four countries that make up the Pampa, Brazil, Argentina, Paraguay and Uruguay) and North American conservation organizations is justified by the importance of this biome in maintaining migratory birds, which are threatened by the advance of soybeans and wood species used for cellulose (Alianza del Pastizal, 2023).

2.1 Destruction and techniques to avoid it

But it is impossible to ignore the fact that these native pasture areas, despite their importance, correspond to a minority of the soils on which cattle farming is carried out in Latin America and the Caribbean. Grazing livestock on the continent is very often marked by low productivity, destruction of biodiversity, monotony in the types of pastures planted, erosion, and loss of the soil's capacity to store carbon. An aggravating factor in these problems in the Pan-Amazon and the Brazilian Cerrado is the fact that the mechanism for occupying what will become low-quality pasture areas has much more heritage than productive purposes. A total of 75% of the

forest that has been lost in the Brazilian Amazon to date is occupied by livestock farming, the precariousness of which could not be greater (Moutinho & Azevedo-Ramos, 2023; Albert et al., 2023). This concern is due to the fact that pasture degradation time in the Amazon is shorter than in the Atlantic Forest or Cerrado. Limiting the occupation of new areas is essential not only to preserve forest socio-biodiversity, but also to reverse the low productivity of livestock farming. Today, degraded pastures in the Brazilian Amazon alone amount to 56 million hectares (Valentim e Andrade, 2020). In Colombia, no less than 60% of pastures were in a state of degradation (Agronegocios, 2019).

Even in areas of native pastures, the threats are significant. The South American Pampa covers 6.1% (108.9 million hectares) of South America. The net loss of native pasture vegetation between 1985 and 2021 was 8.8 million hectares. The combined area of planted agriculture and pasture grew by 10.6%, from 44 million hectares to 48.6 million hectares, and the area planted with exotic trees increased from 600,000 hectares to 2.8 million hectares (an increase of 363%) (Brasil, 2023). This conversion reduces the composition and variety of the fauna (Serafini, 2013; Staude et al., 2021) and flora communities (Porto et al., 2022, Smith et al., 2022) of the soil, and can affect the ecosystem services offered by this biome.

Thus, biomes that are suitable for cattle farming, such as the Pampa (Arantes et al., 2018; Matte & Waquil, 2020, 2021; Carvalho et al., 2021; Guarino et al., 2023; Moreira et al., 2023), the Pantanal (Seidl et al., 2001), and the Cerrado (Euclides Filho, 2008; Nanzer et al., 2019; Victoria et al., 2020; Vigroux et al., 2023), could - if used and managed properly (Feltran-Barbieri & Féres, 2021; Moojen et al., 2022; Leroy et al., 2022; Beal et al., 2023) - meet current market demand without increasing the areas they occupy today (Arantes et al., 2018; Carvalho et al., 2021; Feltran-Barbieri & Féres, 2021), conserving biodiversity by maintaining pastures (Arantes et al., 2018; Alexandre et al., 2021; Jaurena et al., 2021; Carvalho et al., 2021; Cunha et al., 2023), and reducing greenhouse gas emissions from livestock (Nanzer et al., 2019; Arango et al., 2020; Zubieta et al., 2021; Damian et al., 2023; Congio et al., 2023). One of the important factors in realizing this potential, as will be seen in the next section, is the appreciation of native species and their diversity. Pastures with legumes, as recommended in the Guaxupé method, increase protein and mineral calcium (Ca) and phosphorus (P), improve the diet of animals and fix nitrogen in the soil through symbiosis with bacteria of the *Rhizobium* genus (Nascimento et al., 2021).

Animals raised on well-managed pastures with high nutritional value emit fewer greenhouse gases than animals raised in confinement, mainly due to the variation in enteric fermentation of the diet and the reuse of manure in soil fertilization (Belflower et al., 2012; Bogaerts et al., 2017; Franzluebbers, 2020; García-Souto et al., 2022). Beef production systems in areas with diversified and well-managed pastures can reduce the area needed for animal husbandry by up to seven times (Cardoso et al., 2016; Köberle et al., 2023).

In addition, several studies (Li et al., 2016; Kinley et al., 2020, 2021; Glasson et al., 2022) show that the addition of algae, especially *Asparagopsis taxiformis*, also known as red algae, has good results in reducing methane gas emissions in ruminant digestion. Some research has shown a reduction of more than 50% in enteric methane emissions by lactating dairy cows (Roque et al., 2019) and more than 80% by beef steers supplemented with algae (Roque et al., 2021).

2.2 Measuring emissions

The consequence of these innovations of moderate intensification is decisive for the very notion of regenerative livestock. As Scoones (2022) rightly points out, "the notion of 'livestock sector' presented in many global assessment reports is largely meaningless". Between basically

confined husbandry (*industrial factory farms*) and farms with open pastures in the Pampa, for example, the dynamics of emissions and the solutions to deal with them change radically.

These changes are even reflected in the emission measures for the cattle herd. The data on their emissions comes mainly from the respiratory chambers of confined animals, especially in the United States and Europe. The report published by Houzer & Scoones (2021) shows that almost all (86% of a total of 164) of the life cycle analyses focused on emissions from cattle farming come from Europe, the United States, Australia or New Zealand. 9% of these analyses come from Asia, 4% from Latin America and the Caribbean and 0.4% from Africa. Measuring emissions from livestock loose on pasture is immensely more difficult. Scoones (2022) shows that both the Intergovernmental Panel on Climate Change (IPCC) and the Eat Lancet (Willett et al., 2019) make the mistake of generalizing methane emissions from confined cattle as if they were universally the same for the entire world's herd. One of the most cited scientific papers on emissions from cattle farming (Poore & Nemecek, 2018), published in Science, advocates a drastic reduction in human consumption of its products based on the systematic underestimation of the importance and particularities of pasture-based farming. Of course, following the guidelines of the most important food guides in the world (and especially in Brazil), the necessary diversification of diets involves reducing meat and increasing fruit, vegetables and legumes in meals. But what these studies tend to underestimate is the potential that pasture-based cattle farming offers for an adequate supply for human needs and, at the same time, whose production can be regenerative and represent a low opportunity cost in what the cattle consume.

Cattle farming can make highly relevant contributions to sustainable development in Latin America and the Caribbean through regenerative practices that, in the overwhelming majority of cases, are well-known, relatively inexpensive, economically profitable, and can be taken to millions of farmers. Let's take a closer look.

3 Regenerative livestock: principles and practices

When you search Google Scholar for the term "*regenerative livestock*", no more than 68 references appear. Few of them define the term. However, it is still possible to resort to this literature to use the term in an operational way. What predominates in definitions of regenerative livestock is the relationship between soils, pastures, animal welfare, and human working conditions. The emphasis is on soil management, pasture quality and herd health as a condition for minimizing dependence on both chemical inputs and "external foods" (Serrano-Zulueta et al., 2022). In their interesting survey of sustainable farming and forestry experiences in Latin America, Miatton & Karner (2020) use the definition of Rodale Institute (2014), which insists on the idea that farming practices must regenerate the resources on which they themselves depend.

Regenerative livestock is an economic activity, which is why Spratt et al. (2021, p. 15), according to whom "regenerative grazing is an agricultural practice that uses principles of soil health and herd management to increase farm profitability, human and ecosystem health and food system resilience". Lal (2020) emphasizes the reduction or elimination of synthetic inputs, the diversity of animals, plants and microbial life, and the ability to generate income to maintain the activity. Living soils, vigorous and diverse plants, healthy animals, decent work, and economically remunerative activity are the general components of regenerative livestock.

Learning from nature is also a general guideline of regenerative livestock: "It's about replicating, on the scale of cattle farming, the dynamics of wild herbivores in pasture ecosystems, such as those observed in savannas" (Serrano-Zulueta et al., 2022, p. 2). Finally, the core of this

way of livestock farming is to respect the sociocultural predispositions of rural populations and their relationship with the livestock way of life. As Evans-Pritchard (2013, p. 27) described when referring to cattle farmers in Ethiopia, "The Nuer tend to define all social processes and relationships in terms of [cattle]. Their social language is a bovine language".

Despite its socio-economic importance for the different Latin American and Caribbean countries, for their exports and for the domestic market, cattle farming in Latin America and the Caribbean is currently marked by low productivity and is very often associated with the destruction of natural environments. The average stocking rate of pastures in the Brazilian Amazon, for example, is 0.73 AU/ha, when the average potential is 2.5 for cattle grazing in the region (Froehlich et al., 2022). Köberle et al. (2023) point out that increasing beef cattle productivity is already widely recognized in Brazil as having great potential for the sector to increase production and, at the same time, reduce the pressure to expand into new areas of land.

In short, however polysemic the notion of regenerative livestock may be, in Latin America and the Caribbean its usefulness derives from two crucial considerations. Firstly, it's not just a question of dissociating cattle farming from the different forms of forest destruction. The largest Brazilian meatpacking plants have made formal commitments to promote this dissociation by the end of this decade (Garrett et al., 2019). But it is clear that this is a starting point and not an end point.

The second fundamental consideration is the urgent need to ensure that Latin America and the Caribbean's advantage of being the region with the highest proportion of pasture-based livestock farming is not only expressed in zero deforestation, but also in the diversification of pastures and animal breeds, increased yields, neutralizing methane emissions, increasing carbon in the soil, enriching biodiversity, animal welfare, decent human work, and economically feasible activity.

It is in Latin America and the Caribbean (more than in any other region of the world) that the term regenerative cattle farming can no longer be seen as an oxymoron. It is true that livestock currently plays a key role in emissions, especially of methane and nitrous oxide. Brazil, for example, is the fifth largest emitter of methane in the world, according to data from the Greenhouse Gas Emissions Estimates System - SEEG (Alencar et al., 2022). Almost half of Brazil's emissions come from deforestation and another 27% from agriculture, with cattle farming accounting for the majority. A study by the NGO Global Forest Watch (2023) revealed that in 2022 Bolivia lost 594,000 hectares of vegetation cover, which is equivalent to emitting 298 million tons of carbon dioxide into the atmosphere. 72% of the total loss was the result of deforestation for the production of *commodities*.

Bringing deforestation to zero and drastically reducing emissions from cattle farming are the possible ways for Latin American and Caribbean countries to reduce their emissions, strengthen the biodiversity of their biomes, and rationalize a fundamental economic activity that is today so strongly marked by backwardness and destruction. Recovery of degraded pastures, biological diversification of cultivated species, crop-livestock-forest integration, together with genetics that encourage diversification and the adaptation of breeds to different climatic situations, are innovations that don't require huge investments, that can be widely distributed in society and whose positive effects on cattle farming in Latin America and the Caribbean can be seen in a fairly short time.

3.1 Soils, plants, animals, and people: the foundations of regeneration

The fact that the vast area of native pastures on the planet's surface provides ecosystem services for which the presence of large animals is decisive is something that has already been established in the best recent scientific literature (Manzano et al., 2023b; Leroy et al., 2023; Beal et al., 2023). But can these services exist (and within the framework of viable socio-economic

activities) in forest ecosystems or in those where the introduction of pastures was based on large-scale biological destruction? Is it possible to promote a radical dissociation between cattle farming and the loss of ecosystem services linked to soil carbon storage, greenhouse gas emissions, biodiversity, and the exploitation of water resources? More than that, is it possible to give this dissociation an economically relevant scale or is it doomed to be confined to virtuous market niches, but with a necessarily limited social reach?

The answer to these questions lies in the relationship between soils, plants, animals and people, and if the promising nature of this relationship can be summed up in one word, the term to use is diversity (Abramovay et al., 2023). Latin America and the Caribbean have a wide diversity of pastures and breeds that pave the way for the socio-environmental and economic feasibility of the most important challenge facing livestock: reducing the space currently occupied by pastures and, at the same time, increasing productivity per hectare, reducing animal finishing times and, therefore, their emissions (Barreto, 2021). This includes, of course, scientific research into the different types of soil and their suitability, as well as research that can help farmers manage their livestock: concentrating calf birth times, for example, is manageable and can offer an advantage to producers, as it increases their negotiating margins when selling the animals due to the homogeneity of the batch and their weight gain. This way, more animals are sold at the same time, reducing costs for the whole chain. Picketing, mineral salt and the afforestation of pastures are also accessible techniques that can increase productivity by reducing life expectancy and the need for new areas.

Proper soil management in native pastures or through diversified cultivation in cultivated pastures makes it possible to capture and store significant amounts of carbon in a way that is integrated with production, which allows for a neutral or positive balance and, consequently, contributes to mitigating climate change. The use of monoculture in pastures invites the invasion of pests, since it reduces the diversity of beneficial insects (Silva, 2022); an example of this is the attack by the pasture leafhopper (Valério, 2009). The heterogeneity of the systems and the genetic improvement of the animals are characteristics of the resilience of regenerative livestock.

There are studies (Valentim et al., 2001; Pereira et al., 2016) showing that, in Latin America and the Caribbean, there are different types of grass with high protein levels and rapid development that could be used in pasture composition. But seed markets tend to concentrate on a few species, thus inhibiting farmers from taking advantage of the region's huge biodiversity. Cattle farmers with greater access to technology and technical assistance make use of this information.

Moderate intensification (Poccard et al., 2015) of cattle farming is the main strategy for reconciling increased productivity with reduced socio-environmental impacts in Latin America and the Caribbean. This intensification is associated with the reform or recovery of pastures, which includes the supply of nutrients, mainly nitrogen (N), which can occur through the application of chemical or biological fertilizers. The high cost of chemical fertilizers limits the adoption of pasture fertilization by Latin American and Caribbean producers, as well as leading to external dependence. In this scenario, the adoption of grass and legume pastures aims to make up for this shortfall and promote biological N fixation (BNF), without the need for external inputs (Brasil, 2021).

3.2. Innovating at low cost

Most importantly, this is moderate intensification (Pacheco et al., 2017; Köberle et al., 2023), the costs of which tend to be affordable for family farmers and the implementation of which does not require sophisticated technological skills. It is an activity that benefits from the

abundance of solar energy and rainfall in the region and relies fundamentally on renewable and abundant resources. If extensive livestock farming maintains biodiversity but with low production, and intensive livestock farming increases production but uses chemical inputs that often compromise biodiversity, moderate intensification has the virtue of reconciling biodiversity with high production performance.

The adoption of legumes in the formation of pastures, in consortium or exclusively, is guided by the choice of crop best suited to the environmental conditions, the nature of the property, the capacity for intervention, and the availability of resources, among others. In this context, trained technical assistance is essential for making decisions and drawing up the right management plan for these pastures.

Last but not least, there is a considerable diversity of cattle breeds. In Latin America and the Caribbean, you can find mixed, pure European and Zebu breeds, as well as Creole and native breeds. The good performance of regenerative livestock depends on choosing breeds that match the potential of the environment, adopting genetic improvement whenever possible.

Integrated crop-livestock-forestry (iLPF) systems are an important tool for sustainable food production. This is because they provide ecosystem services and contribute to social benefits, such as generating demand for labor, resilience to economic factors and risk reduction. For example, conventional livestock generates one new job for every 1,000 steers, while the iLPF system generates more than one direct job for every 100 hectares of pasture (Oliveira et al., 2013).

iLPF systems are a production strategy in which forestry, agriculture and livestock components are synergistically integrated on the same temporal or spatial scale. This method seeks to maximize production and product quality while respecting the social and environmental dimensions. Among its benefits are: optimization and intensification of nutrient cycling in the soil, improvement of animal welfare due to greater thermal comfort, diversity of products that can be generated in the area, such as grains, meat, milk and wood and non-wood products, and, consequently, greater financial security for the farmer, more job creation, carbon storage and the possibility of being applied to properties of any size (Behling et al., 2013; Domiciano et al., 2018; Giro et al., 2019).

Crop-livestock-forest integration improves the soil's chemical, physical and biological attributes, with an increase in organic matter. This management can also increase the productivity of soybeans grown in these areas by 20%, the stocking rate of pasture by at least five times, meat productivity by eight times, and reduce the slaughter age by one year, which leads to a reduction of at least a quarter of methane per kilo of meat produced (Oliveira et al., 2013; Garrett et al., 2020).

In addition, crop-livestock integration under moderate intensity grazing resulted in better carbon stock levels, higher forage production and liveweight gain, and greater resistance to moderate and extreme weather events (Delandmeter et al., 2024). This is because the presence of domestic herbivores plays a positive role in the carbon cycle (Fundación para la Conservación del Bosque Chiquitano, 2020) and aids in greater biomass production through manure and urine during the grazing period or as a final residue of the season (Delandmeter et al., 2024). This accumulation of organic matter in the soil also tends to increase the resilience of systems to climatic disturbances (Franzluebbers, 2010).

In this way, it can be seen that there are managements that allow for an increase in production while reducing greenhouse gas emissions, such as methane. One study analyzed 24 methane mitigation strategies in Latin America and the Caribbean. 58.3% of the strategies involved cattle grazing (Congio et al., 2021). Of these, 16 showed decreases in methane without compromising

animal productivity and, of these, six reduced methane emissions by approximately 27% and increased animal productivity by around 68%.

Practices such as forage diversification, mixed crops of grasses and legumes with a high soil fertility recovery content, rational grazing and agroforestry cultivation are examples of regenerative management that increase animal productivity. For over ten years, Fundación para la Conservación del Bosque Chiquitano (FCBC), a Bolivian non-governmental organization, has been carrying out research into the interactions between regenerative livestock and biodiversity in the region, and the application of such management has made it possible to double the animal load per hectare: the average productivity is usually 1 to 1.5 AU/ha in the region, and in these areas with regenerative livestock practices they reach 2.3 AU/ha (Fundación para la Conservación del Bosque Chiquitano, 2020).

The Promoting Climate Smart Livestock Management project (Ganadería Climáticamente Inteligente en la República Dominicana, 2022) in the Dominican Republic covers eight provinces in the Yuna River basin. On a family farm, the project implemented techniques such as a drip irrigation system, rotational grazing management, afforestation and shading, planting selected grasses, creating a Mulberry protein bank, and recording of production activities, which increased productivity by 117% in two years, reduced greenhouse gases by 19%, increased the availability of pasture and fodder, and promoted greater vegetation cover on the farm, which led to greater carbon capture.

It is part of the regenerative nature of livestock farming that cattle food is not based on products that can be consumed by humans, i.e. the low opportunity cost of animal food (van Zanten et al., 2023). In regions with rich biodiversity, not only can pastures increase their feeding power by introducing legumes and diversifying species, but the finishing phase of the animals, which often relies on grain consumption, can also be based on products that don't compete with human food, such as cottonseed and wet barley residue. In addition, cassava stalks are an important example, as they are widely available in Latin America and the Caribbean. But it is clear that, in the context of crop-livestock-forest consortium, the potential is immense for Latin American and Caribbean livestock farming, even in its final stages, not to require products that can directly supply human food needs. Eduardo Roxo Franciosi (2022) shows the immense potential for integrating babassu (found on no less than 15 million hectares of the Mata dos Cocais, in the Brazilian State of Maranhão) and livestock farming.

For regenerative practices become real, it is important to promote technical assistance and rural extension, through training that dialogues with the local reality of livestock farmers, in order to overcome the specific challenges of each region, such as the lack of infrastructure, and which are based on respect for different cultures.

4. Conclusions

Reducing emissions from livestock, making cattle farming a key component in the regeneration of biodiversity and thus expanding the supply of food essential to human health are objectives whose technological bases and economic costs are much lower than those of decarbonizing the industrial sectors that emit the most greenhouse gases. The technical knowledge needed to generalize regenerative cattle farming in Latin America and the Caribbean already exists and can be implemented in the short term.

This transition does not mean expanding the area currently occupied by cattle farming. On the contrary, it is essential to reduce it, especially in regions where livestock farming has caused significant degradation, such as the Amazon. This reduction requires technological improvements that promote carbon storage in the soil and increase the productivity of cattle

farming. The main strategies include pasture diversification, the consortium with legumes and trees, managing calving periods, and improving and diversifying breeds. These changes are accessible to farmers of all economic sizes and their individual and social returns are quite fast.

The potential gains from this transformation are immense. If its adoption is still slow to this day in the territories most susceptible to degradation, it is because credit policies have focused much more on the acquisition of animals than on the transformations that will allow them to be managed more appropriately. To facilitate this transition, it is essential to change these policies to support the necessary technological and management changes.

The basic premise for these innovations is zero deforestation. The establishment and application of zoning regulations that designate areas suitable for cattle farming, together with targeted credit policies and technical assistance, will improve the economic and socio-environmental performance of cattle farms. This approach will guarantee a sustainable food supply, strengthen soil carbon storage, biodiversity and farm profitability.

Regenerative cattle farming is perfectly in line with the dietary recommendations of the most important food guides in Latin America and the Caribbean, which advocate reducing the consumption of animal products and diversifying diets. It supports a culinary culture in which animal products and their derivatives are just one component among a variety of nutritious foods.

No other economic sector in Latin America and the Caribbean has the potential to transform itself in the direction of biodiversity regeneration as quickly, cheaply, profitably, and technically as cattle farming. It is essential that governments, companies and civil society take advantage of this asset to strengthen sustainable development in the region.

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RA: Conceptualization, Methodology, Formal analysis, Resources, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition.

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ECS, ALR and MWG: Writing – original draft.

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Nothing to declare.

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Research data is available through the DOI.

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