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Agricultural and livestock production in the Amazon: a reflection on the necessity of adoption of integrated production strategies in the western region of the state of Pará

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Abstract

The Brazilian Amazon has a large bovine herd and is an important exporter of meat from cattle and is also one of the most competitive regions for exportation of animal protein. Conventional extensive cattle ranching management has been a strategy promoted by public policies and has contributed to the processes of occupation of the region through modification of public lands with native forests. The objective of this study was to analyze the fundamental elements that have sustained conventional extensive cattle ranching in the Amazon and to demonstrate new strategies to change this paradigm, with a focus on western Pará. Data from the Brazilian Institute of Geography and Statistics (IBGE) on cattle ranching production between 1990 and 2019 were analyzed and separated into two periods, 1990-2000, and 2001-2019. Meteorological data from western Pará were analyzed to describe the agrometeorological conditions (1989 -2012) with respect to the hydrological regime and its controls on the soil-plant-atmosphere system. Results show that the largest greenhouse gas emissions (GGE) from ruminants occurs during the dry season due to pasture forage grasses that are highly lignified. In contrast, lower emissions occur from diets rich in proteins and lipids, with subsequent gains in productivity, thus indicating the benefits of pastures with well-managed grasses. It is believed that cattle ranchers will adopt integrated systems such as integration of crop-livestock-forest (ICLF) when they are able to understand that climate conditions can be allied with sustainability indicators of the production chain. This paradigm shift in production systems applies not only to environmental and economic aspects, but especially to social ones such as opportunities to hire qualified workers coming from regional agrarian science schools.

Keywords: Amazon rainforest, agriculture, integrated systems, sustainability.

Introduction

The increase in the concentration of greenhouse gases (GEE) in the atmosphere has been steadily intensifying, as shown by the Intergovernmental Panel on Climate Change (IPCC), and the majority of this increase is attributed to anthropogenic actions. In Brazil, the production sector that has the largest portion of GEE emissions is agriculture and cattle ranching. In 2014 in Brazil, these activities represented about 20% of the national total of GEE emissions (SEEG, 2016). Specifically, in cattle ranching activities, one of the principal contributors to GEE emissions is methane (CH_4), which is produced by enteric fermentation by ruminants, and these emissions represent 68% of total emissions from the cattle ranching sector (Berchielli et al., 2003). It is important to emphasize that this

elevated emission of CH_4 is a result of the low efficiency of the use of energy consumed in the diet which subsequently reduces productivity. The principal factors controlling GEE emissions from bovines are attributed to the quality of pasture grass, the ratio volume, concentrate in the diet, the efficiency of digestive system processes, and the age at slaughter. It is important to emphasize that there exists a diversity of strategies for the reduction of GEE emissions in cattle ranching activities, such as adoption of specific nutritional and reproductive regimes, and improvement of general management practices (Carvalho et al., 2011; Berndt, 2012). Lipid supplements in ruminant diets (Roqueta-Rivera et al., 2010) represent an alternative that can be incorporated to reduce emission of CH_4. For example, for each 1% gain in fat in the diet of dry matter consumed by bovines there was a reduction of up to 6% of CH_4 kg^{-1} (Abdalla et al., 2008; Grainger et al., 2008). Sustainability indicators in cattle ranching activities need to consider the production of meat and milk in consonance with conservation of soil, hydrological resources, and native forest conservation.

Among these indicators are the total area annually incorporated into production systems in Amazonia that are originated from pastures undergoing processes of degradation (Dias-Filho, 2011), meaning that these areas do not enter into the statistics of forest loss through illegal deforestation, landowner/cattle rancher respect for the legal rights of rural farm workers, the existence of a profit margin sufficient enough to maintain the dignity of agricultural producers, and fulfillment of the regulations of the Forest Code. According to Berndt (2010), practices that reduce annual GEE emissions such as the conservative use of water for consumption by animals, as well as adequate management of soil and pastures can be included as indicators of sustainability. The improvement of pasture conditions, besides providing forage with higher nutritional quality, will also increase the stocks of carbon in soil and enable adequate management of bovines with respect to the carrying capacity of the cultivated pasture grass, thus increasing the potential for mitigation of emissions of GEE from these cattle ranching systems (PBMC, 2012). Change in the perception of rural producers with respect to agricultural management practices occurs when there is a dire necessity for recuperation of degraded pastures, and when this can be conciliated with positive economic returns and legislation which requires no new deforestation. The adoption of a set of good management practices can advance agricultural and cattle ranching production while at the same time helping to establish sustainability indicators. The social and environmental benefits are evident, since the incorporation of integrated systems improves pasture quality, and the addition of forest species to pastures promotes animal comfort (Sousa et al. 2016), and a gain in herd productivity. Longhini et al. (2016) relate that in integrated production systems there is greater availability of forage in pastures and consequently higher animal productivity. The objective of this research was to conduct an analysis of conventional extensive cattle ranching in the Amazon, and to highlight the importance of the adoption of integrated production systems, with focus on areas of agricultural production in the western region of the state of Pará.

Results and discussions

The schematic diagram (Figure 1) illustrates the importance of the fact that production systems must guarantee a good supply of pasture as well as promote the development of strategies for nutritional supplementation to maintain acceptable levels of production of the herd during seasonal climatic periods that can cause nutritional deficit due to a reduction in the quality and quantity of forage in pastures.

Figure 1 shows a schematic diagram of response variables that contribute to metabolic processes and the digestion of forage grass by animals. Understanding the principal variables for model input, the boundary conditions can be established to quantify animal GEE emissions.

This stylized design serves to facilitate the comprehension of rural agricultural producers in relation to the necessity for the development of partnerships with researchers in order to adopt management techniques that will reduce GEE emissions. This will allow for creation of economic, social, and environmental sustainability indicators which can subsequently be used as an aid in the creation of public policies that will support production in cattle ranching systems in the Amazon.

In terms of external environmental conditions, and within the installed physical space, it is necessary to evaluate the direct and indirect effects of animal production during the entire production cycle, because these can influence the indicators of production and sustainability, possibly causing considerable economic losses.

The time of year, and thermal and hydrological conditions are input variables for the thermal-hydrological comfort analysis of animals. Physiological responses of the animals or adaptation indicators can be explained through knowledge of agrometeorological variables. This, in turn, can support decision-making processes with respect to management, nutrition, adjustment of installations and improvement of physical space including trees for provision of shade and inclusion of monitoring equipment, among other actions that can maximize the production of cattle ranching systems in the region.

In this way, the word “ambience” is related to comfort, which signifies the thermal comfort zone of each species, as a function of physiological characteristics that regulate the internal temperature of the animals and affect animal well-being. In this sense, factors that provoke stress are minimized, and the availability of forage, water, and shade for the herd in the pasture is increased, with a subsequent reduction of the carbon footprint.

Figure 2 shows the monthly variability of rainfall in the lower Amazon region, where there is an important agricultural production center in western Pará. These data can be used to aid in planning of integrated production systems in the region, and it is important to emphasize here that most cattle ranchers in this region still adopt the extensive ranching system.

These rainfall data show that there is a clear and contrasting pattern of the volume of monthly rainfall during the year, and this will have a strong effect on pastures and agricultural crops in this region during the months of January to May; however, this situation is reversed during July to November, the period with less rain. Therefore, it is plausible to suggest that rainfall up to the month of July can extend the period that animals can remain in well-managed pasture.

In an agrometeorological context, during the months when the soil has sufficient water stocks to meet the demands of plant evapotranspiration (Martorano et al., 2017), it is assumed that pasture grasses will have their largest production of green biomass (Gomez et al., 2013), meaning that leaf area index will be at a maximum, thus resulting in weight gain in pasture animals.

The region is characterized by rainfall events during all seasons of the year, which permits a substantial availability of pasture during part of the year. Another aspect that should be highlighted here is the inclusion of grains in integrated systems of production. Since soybeans are associated with a greater profit margin and ease of export through the port of Santarém, the management cycle of grains production often does not include crop rotation and succession practices.

Research is showing that a paradigm shift is necessary with respect to cattle ranching in the Amazon region. The strategy for such change would be to increase the competitiveness of meat produced for export that is produced in areas that were previously deforested and that contribute to reduce the pressure on native forests that is applied by cattle ranchers seeking to increase productivity.

Soybean production generates a large quantity of byproducts that can be used to produce feed with low transport costs. Cattle ranchers need to invest in nutritional supplements, such as soybean byproducts, and adopt integrated production systems such as crops/livestock or crops/livestock/forest to increase the competitiveness of agricultural activity in the Amazon and increase the viability of these production systems with respect to environmental questions (Amaral Junior et al*.,* 2015) and emissions of GEE.

The development of cattle ranching activities in areas that are currently dedicated to the cultivation of soybeans could represent a strategy for the adoption of integrated systems, thus increasing the efficiency of production processes in areas that have already been modified by human activity. The period in which these agricultural areas are being used for cattle grazing on forage will break the cycle of pests and grain diseases, besides creating good conditions to take advantage of field stubble from the harvest of the previous crop, and of byproducts from grain processing in the same production area.

The region of western Pará has the potential to stimulate the harmonious integration of agricultural and cattle ranching systems. For example, the second harvest, called the "safrinha", which is generally corn, is harvested during August and September and the price of this harvested corn is usually low enough during this period that cattle ranchers can use it as a feed supplement for their herds, which helps to reduce water stress in pastures during these months.

Another management option employed in this region is the strategic confinement of part of the cattle herd during this period of lower pasture production, along with the finishing of the herd using whole grains, which is a management practice that has become more common in this region (Neves et al*.*, 2014).

Another important factor that should be considered in the adaption of integrated systems is that carrying capacity of integrated crop/livestock systems (Balbino et al., 2011) will depend on the availability of rainfall, the physiology of cover crops, the pasture rotation cycle, and the supply and demand for animals in the market during the short interval between two crop plantings. This capacity will also depend on byproducts coming from grain production and the availability of animals and infrastructure on the property such as fences, feeding stalls, water source, management areas, and aptitude of farm workers.

The traditional systems of use and occupation of land have accumulated environmental liabilities that could be resolved to make farms be in compliance with current legislation such as the Brazilian forest code, public policies, and international agreements that require low carbon emissions (ABC Program and the IPCC), and that incorporate new technologies and production systems. The expansion of cattle ranching has been strongly associated with policies of territorial occupation, road construction, clear cut logging, and pig iron production. This model primordially follows a chronological order with coal production and implantation of pastures after burning native forests. Figure 3 shows a chronological series of the expansion of cattle ranching in the State of Pará, which has 10% of the bovine herd of Brazil (IBGE, 2016).

With respect to the cattle herd of the state of Pará, there is a greater concentration in the southeast region of the state, with more than 14 million head of cattle, which represents nearly 70% of the total in the state (Figure 4). Up to 2005, this region represented nearly 75% of the herd of the state of Pará, but the dynamic of cattle ranching activities in the region has been characterized by low indices of sustainability due to a low number of heads of cattle per hectare and deforestation for wood extraction and coal production.

Therefore, as a preventive measure, the state conducted direct interventions to control deforestation, such as putting restrictions on agricultural products coming from properties in municipalities with higher indices of deforestation (Reydon, 2011). The northeastern region of the State of Pará, with a strong presence of agricultural and cattle ranching activities was first settled more than 300 years ago.

This situation is contrasted with that of the Amazon in general, which experienced strong pressure to deforest as a direct result of public policies that organized territorial occupation in the decade of the 1970s (National Integration Plan – PIN, Decree-Law n. 1.106/1970) with slogans such as "integrate in order to not giveaway", and "land without men for men without land".

These public policies influenced the expansion of agricultural and cattle ranching activities into the region, and the government reserved areas for colonization and for agrarian reform, meaning the allotting of parcels of land to foment small-scale family-based agriculture, usually along important Federal highways which were constructed during this period. The southeast and southwest regions of the state of Pará concentrate the largest portions of the cattle herd in the state (Figure 4).

Occupation of lands through the actions of social reform organizations and division of agrarian reform settlement lands into smaller parcels has occurred in recent years with studies examining economic, social and environmental viability in the state of Pará. Many instances of land expropriation have occurred due to invasion and squatting on lands and pressure from social reform organizations.

The spatial-temporal distribution of the cattle herd in the state of Pará in Figure 5 shows that since 1990 the herd grew, especially along the Transamazon (BR 230), Belém-Brasília (BR 010) and Santarém-Cuiabá (BR 163) highways. Furthermore, it is evident that the herd is concentrated in the south and southeastern regions of the Amazon in general, specifically in the states of Tocantins and Mato Grosso, where the herds were consolidated between 2001 and 2019 (Figure 6).

Use of byproducts from agroindustry in cattle ranching activities has grown around grain production regions to supplement animal diets based on pasture or in feedlots to improve productivity. Nutritional supplementation in ruminants is a strategy to reduce methane (CH_4) emissions.

Results from the Amazon biome using palm cake in buffalo feed during the dry season show that the inclusion of palm cake in a proportion greater than 0.50% of the live weight of the animal resulted in lower enteric methane emission

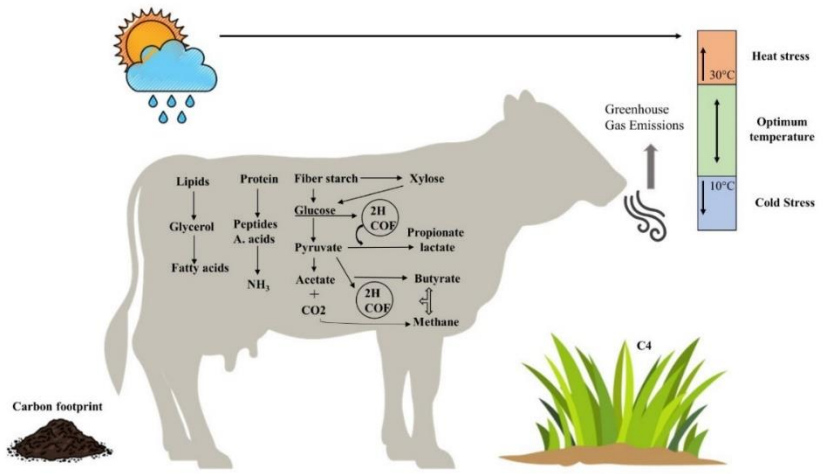

Figure 1. Schematic diagram of possible input variables for the establishment of boundary conditions for the evaluation of greenhouse gases from cattle ranching in the Amazon.

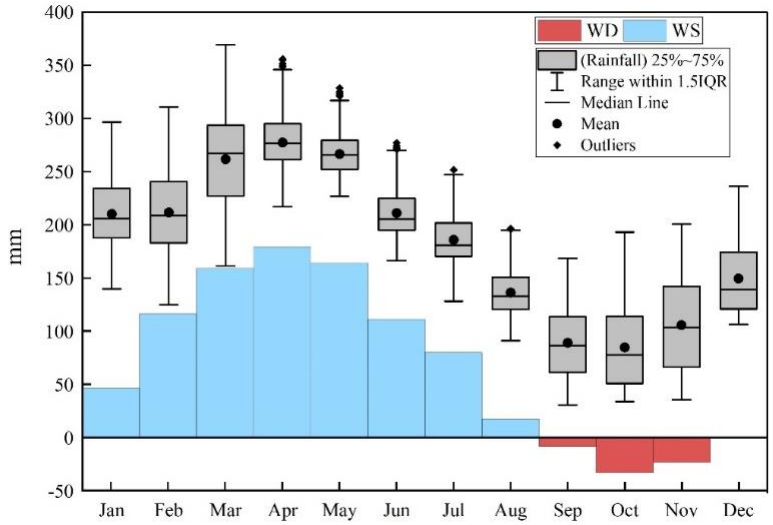

Figure 2. Variability of rainfall from 1989 to 2012, western Pará.

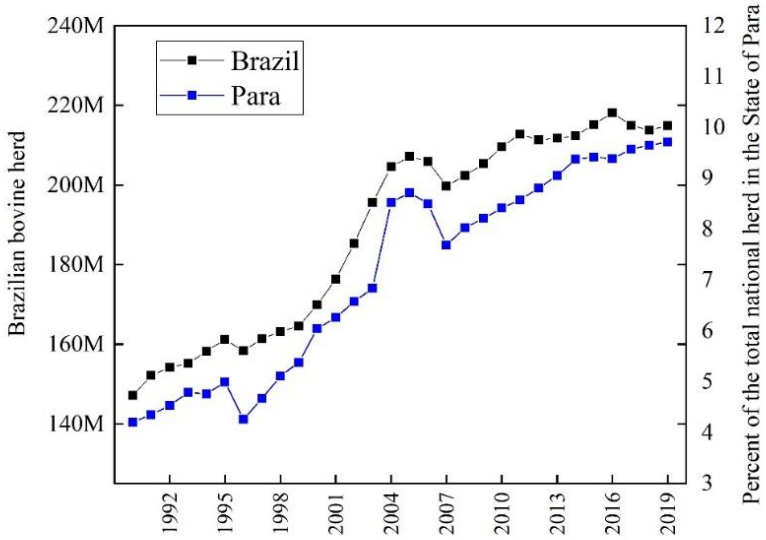

Figure 3. Bovine herd in Brazil (1990 to 2019) and the percent of the total national herd in the state of Pará, Amazon.

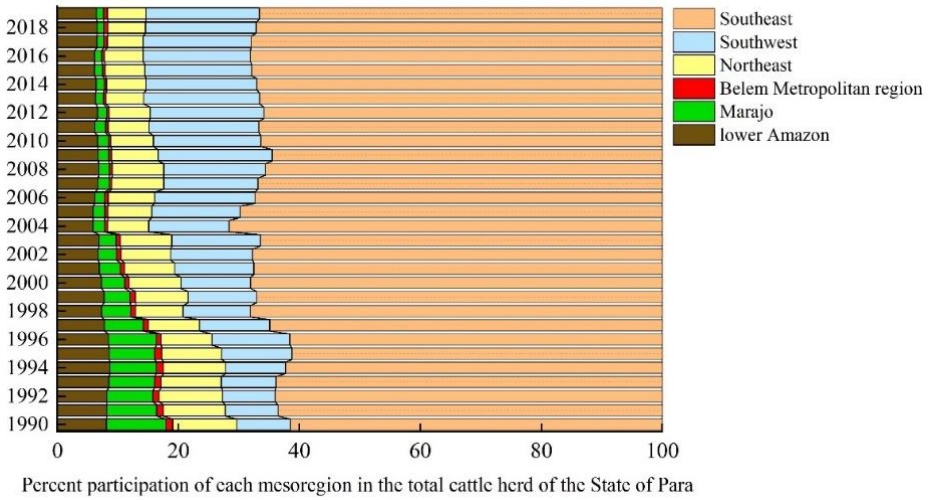

Figure 4. Annual cattle herd by mesoregion compared to the accumulated percentage in the State of Pará.

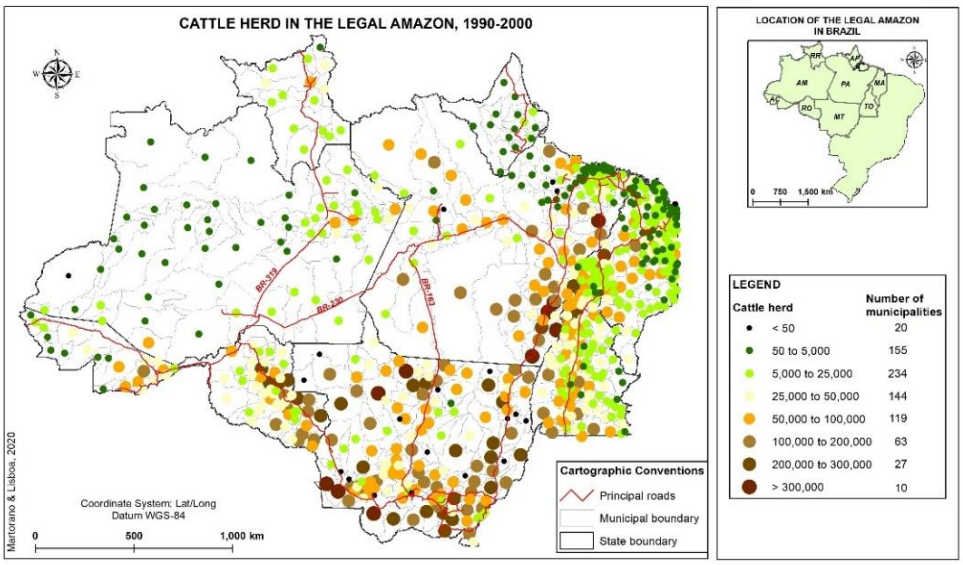

Figure 5. The spatial-temporal (1990 to 2000) dynamics of the cattle herd of the Legal Amazon in Brazil.

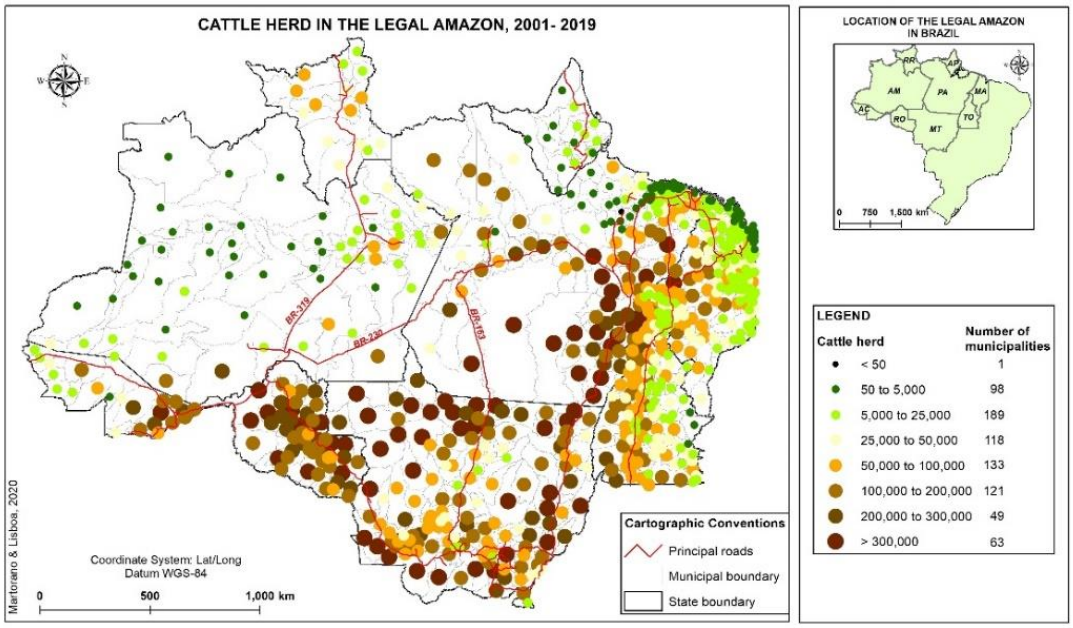

Figure 6. The spatial-temporal (2001 to 2019) dynamics of the cattle herd of the Legal Amazon in Brazil.

(Amaral Junior el al., 2016). The chemical composition of the palm cake contains protein, energy, and a fiber used for nutritional supplementation in feedlots in north of Pará.

The quantities of net protein and ether extract (fat) ingested were greater in the treatment with the maximum inclusion of palm cake 0.70 and 0.47 ($kg.day^{-1}$), respectively. In this way, enteric methane emission was lower in the palm cake treatment at a rate of inclusion of 1%, or 27.65 $kg.year^{-1}$, values that are lower than those estimated by the IPCC equations (2006), which indicates buffalo emission as being 55 $kg.year^{-1}$. Ruminants that were not fed palm cake emitted 78.15 $kg.year^{-1}$ of CH_4.

It is important to stress that the Brazilian buffalo herd is centralized in the north region of the country, with 720,000 registered heads of a national total of 1.15 million, with 39% (461,275) in Pará, according to data from the Ministry of Agriculture, Livestock, and Food Supply. Furthermore, palm oil residuals from agroindustry are abundant in the state during the entire year, and because of these prices would be lower compared to other supplements such as corn, soybeans, and wheat, which are used in animal diets.

These types of actions have the result of integrating agroindustry production chains, thus strengthening alternative strategies for low carbon emission and reducing the footprint of generation of residuals from agroindustry in the region (LISBOA, *et al*., 2016).

According to Neves *et al*. (2014), the adoption of integrated production systems, especially that of crop – livestock, together with reproductive biotechnologies such as artificial insemination in fixed time, will promote sustainability of cattle production in this region of the Amazon.

Materials and methods

Data were used in grid format and obtained from the database of the European Centre for Medium Range Weather Forecasts (ECMWF) for the years 1989 to 2012, using the same assumptions as those in Moraes et al. (2020), and focusing on the lower Amazon region, which has a substantial portion of the bovine herd of the state of Pará. It is important to highlight that this region was the last one included in the classification of regions free of hoof-and-mouth disease, which confirmed the efficiency of government programs to alert and educate cattle ranchers to follow the vaccination calendar established in the state of Pará.

Estimates of the hydrologic balance were done considering the availability of water in the soil as 100mm in order to evaluate the months in which grasses have high protein potential due to ample soil water availability, and also during months when there is potential for loss of biomass due to water deficits. The graphs using these data were elaborated using the Python programming language.

Additionally, data on the size of the bovine herd were used from the database of the Brazilian Institute of Geography and Statistics (IBGE), and were included in the spatial-temporal analysis from 1990 to 2019. Two averages were taken in this analysis, one from 1990 to 2000, the period before the expansion of centers of grain agriculture in the Amazon, and one from 2001 to 2019, the period of consolidation of these centers in the region. After the insertion of the data at the level of municipalities, two maps were generated which show the average values for the cattle herds in the region.

Pastures in the region undergoing degradation processes were gradually substituted by annual crops, principally soybeans and corn, and this had a great impact on the dynamics of agricultural as well as cattle ranching production chains in the Legal Amazon.

An important aspect that must be taken into consideration is that grasses are C_4 plants and use atmospheric CO_2 more efficiently than C_3 plants due to the presence of two enzymes, rubisco, and oxygenase, which provide a series anatomical, biochemical, and physiological advantages that make C_4 plants more productive and tolerant to environmental stresses (Valente et al., 2016, Smith, Dukes, 2013, Hartzell et al., 2018).

This could be one of the reasons that the Brazilian government heavily promoted extensive cattle ranching in the Amazon region as part of the public policies legislating the integration of the Amazon. Financing of projects through the Superintendency for the Development for the Amazon (SUDAM) generated a large carbon footprint by including systems of low productive capacity with an average of less than one animal per hectare (ha), due to the extensive areas with pasture that were degraded as a result of these policies. Agricultural and cattle ranching activities represent an important source of food needed to meet the worldwide demand for increases in the food supply by 2050 as described by various possible scenarios (FAO, 2009), and this sector can also contribute to mitigation actions to reduce GEE emissions (World Bank, 2011). In this context, the Ministry of Agriculture, Ranching and Food Security (MAPA, 2010) created the Program for Low Carbon Agriculture (ABC Program) with the goal of stimulating food and bioenergy production with a concomitant reduction in GEE, as outlined in the Agriculture and Cattle Ranching Plan of 2010/2011.

Among the indicators of GEE emission is CH_4 produced in cattle ranching systems, and these emissions can be measured in diverse production systems using the IPCC equations (2006; 2014). Results from the PECUS (Dynamic of Greenhouse Gases in Cattle Ranching Systems in the Amazon Biome /Project Component 7 - PC7) network demonstrated that in experiments with buffaloes using the sulfur hexafluoride (SF_6) gas tracer method, there were considerable reductions of CH_4 emission in buffaloes that had a dietary supplement of palm cake.

The lowest emissions occurred in animals that received a diet with a greater percentage of palm cake, and these animals had a larger weight gain, and the greatest emissions were produced in the control treatment of animals that did not receive palm cake (Amaral Junior et al., 2015, Amaral Junior et al., 2016).

The diets were tested in periods when there was a reduction in the availability of pasture grass, principally during periods with soil water stress during the dry season in the region (Martorano et al., 2017). Using the IPCC equations (2006) it was possible to inventory the enteric emissions of methane (TIER 1, TIER 2 and TIER 3) using data collected and made available by the Agency for the Defense of Cattle Ranching of the State of Pará-ADEPARA (Castro et al., 2016, Castro et al., 2017). The FAO (2004) emphasized the importance of soil conservation and maintenance of hydrological resources in pastures in tropical climates, and that the interactive processes between the vegetation and atmosphere developed on a local scale are important variables for use in models of production systems.

Conclusions

The expansion of cattle ranching activities in the southeastern and southern regions of the Amazon basin demonstrates that this region requires a change in strategy to maximize pasture

management and nutritional supplementation to guarantee the supply of forage during the dry season.

In the lower Amazon region, water deficits between August and November require feed supplementation during this period. Nevertheless, since most cattle ranchers adopt a system of herd management wherein cattle are rotated between the floodplain and upland areas, it is exactly during this period that cattle raised for meat migrate to the floodplain areas where they experience large weight gain due to the abundance of fertile pastures.

During the rainy season when water levels rise in rivers in the region, these animals are transported to upland areas where there is generally an ample supply of pastures due to sufficient soil water stocks, which justifies the denomination "meat from green cattle" which is applied in the export market.

After 2001 there was large growth in the cattle herd in the state of Pará, and this growth followed the trend of growth at the national level. Between 2001 and 2019 the herd continued to grow in Amazon, indicating the importance of adoption of measures in this region that are in consonance with aspects of the national climate policy such as the low carbon emission cattle ranching (ABC Program).

The adoption of integrated production systems (crop/livestock, or crop/livestock/forest) represents an alternative to increase productivity and sustainability, and this will subsequently improve social, economic, and environmental aspects of the rural environment.

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