SEMINA
Ciências Agrárias

DOI: 10.5433/1679-0359.2022v43n2p541

Patterns of production and sustainability of cattle ranching in the state of Pará - Brazilian Amazon

Padrões de produção e sustentabilidade da pecuária bovina no estado do Pará - Amazônia Brasileira

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Highlights

Factor analysis enabled the development of an environmental sustainability indicator.
There is a strong correlation between the TPI and the average size of the pasture area.
Water protection practices are present on the properties under precarious conditions.
Conservation practices are little used, compromising environmental sustainability.

Abstract

The aim of this study was to analyze the production patterns present in rural properties producing cattle in the micro-regions that make up the state of Pará. Exploratory Factor Analysis (EFA) was applied to identify the patterns, and these data are used to evaluate correlation between the heterogeneity of rural properties and the environmental impact on the identified patterns. The theoretical contribution is based on discussions on global impacts of food production and environmental sustainability and the impacts of livestock production systems in Brazil and the Amazon. Survey data were taken from the 2017 Agricultural Census, available for the 144 municipalities in the state, and pooled into 22 micro-regions. Three patterns of rural properties were identified: the first related to conservation management practices and called transition management; the second highlights aspects associated with information technology and communication (ICT) and productivity called technical productive efficiency; the third indicates the importance of social organization and access to information called social participation. With these patterns, it was possible to develop the Traditional Performance Indicator (TPI), in which the micro-regions of São Félix do Xingu, Itaituba and Conceição do Araguaia were those with the highest values of this indicator, water protection practices are present in the properties, however, in precarious conditions, and conservation practices are rarely used. The correlation between heterogeneity, measured by the size of pasture area in each micro-region, and the TPI is positive, strong and significant. In this transition context, public policies are essential

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Received: May 19, 2021 - Approved: Oct. 09, 2021

to provide access to infrastructure, credit and good animal health and biotechnology practices.
Key words: Anthropogenic actions. Greenhouse gases. Food production. Environmental sustainability.

Resumo

O objetivo deste estudo foi analisar os padrões de produção presentes nos estabelecimentos rurais produtores de gado bovino nas microrregiões que formam o estado do Pará. Foi aplicada a técnica estatística de Análise Fatorial Exploratória (AFE) para identificar os padrões, e com esses dados avaliar a correlação entre a heterogeneidade das propriedades rurais produtoras e o impacto ambiental nos padrões identificados. O aporte teórico está ancorado nas discussões sobre os impactos globais da produção de alimentos e a sustentabilidade ambiental e os impactos da pecuária no Brasil e na Amazônia. Os dados da pesquisa foram extraídos do Censo Agropecuário de 2017, disponíveis para os 144 municípios do estado, e agregados em 22 microrregiões. Foram identificados três padrões de estabelecimentos rurais: o primeiro relacionado as práticas de gestão conservacionistas e denominado de gestão em transição; o segundo destaca aspectos associados a tecnologia de informática e comunicação (TIC) e a produtividade denominado de eficiência técnica produtiva; o terceiro indica a importância da organização social e o acesso a informação denominado de participação social. Com os resultados desses padrões foi possível gerar o Indicador de Desempenho Tradicional (IDT), em que as microrregiões de São Félix do Xingu, Itaituba e Conceição do Araguaia foram aquelas com maior nível desse indicador, as práticas de proteção das águas se fazem presente nas propriedades, porém, em condições precárias, e as práticas conservacionistas são pouco empregadas. A correlação entre a heterogeneidade, medida pelo tamanho da área de pasto em cada microrregião, e o IDT é positiva, forte e significativa. Nesse contexto de transição, as políticas públicas são essenciais para proporcionar acesso a infraestrutura, crédito e boas práticas de saúde animal e biotecnologia.
Palavras-chave: Gases de efeito estufa. Produção de alimentos. Sustentabilidade ambiental. Transformação antropogênica.

Introduction

The world population's access to a nutritious diet and sustainable food production are two challenges for humanity, in which sustainability depends on reducing the emission of greenhouse gases (GHG), protecting lakes, rivers and oceans, and the reduction of climate variations caused by these activities (Ritchie & Roser, 2020).

According to Ritchie & Roser (2020), half of the habitable land on the planet is used for food production. However, it took 300 years to reach this portion of land use for agricultural purposes, moving from a cover classified as wild, which represented 95% lands without ice, in 1700, to 55% in 2000, in which these lands were transformed into pastures, agricultural lands, villages, and other agglomerates (Ellis, Goldewijk, Siebert, Lightman, & Ramankutty, 2010), and show that the terrestrial biosphere has undergone a strong anthropogenic transformation in the last three centuries. This interaction of people with ecosystems resulted in changes in ecological patterns, called by Ellis and Ramankutty (2008), anthropogenic actions on natural ecosystems.

By specifying the distribution of land use, Ellis et al. (2010) showed that this partition of land for livestock production accounts for 77% of the global agricultural area. In this sense, the authors stated that the expansion of agriculture is responsible for the greatest impacts of humanity on the environment and biodiversity, and that the reduction of this impact will depend, in part, on technological advances in the production process.

In this context, there are different agricultural producers, who employ various agronomic techniques and use different inputs for production, which leads to different environmental impacts. Poore and Nemecek (2018) developed models to translate collected data into environmental impacts, using a sample of 38,700 farms distributed in 119 countries and 40 different foods. These authors developed five indicators: land use, freshwater abstraction weighted by local water scarcity, GHG, acidifying, and eutrophication emissions. The theoretical approach used was the product life cycle analysis (LCA), in which the impacts were generated at each stage of the supply chain. The authors demonstrated that the food chain produced 13.7 billion metric tons of carbon dioxide equivalents (CO2eq), 26% GHG emissions; 32% global terrestrial acidification; and 78% from eutrophication, which can modify the species composition of ecosystems.

The results of Poore and Nemecek (2018) also showed that at the initial stage of the supply chain (on the farm), 61% GHG emissions from food are generated (81% if deforestation is included), 79% acidification and 95% eutrophication. The average GHG emission from beef cattle farming was estimated at 50 kg CO2eq per 100 g protein and land use at 164 m2 per year. In the case of dairy cattle producers, the average values of GHG emissions and land use were 17 kg CO2eq per 100g protein and 22 m2 per year, respectively.

In Brazil, livestock production is extensive and is identified by environmentalists as responsible for deforestation and burning of the Amazon Forest (Barreto, 2017; Rivero, Almeida, Ávila, & Oliveira, 2009). In this context, the country assumed the top rank in world beef exports, maintaining trade relations with 180 countries. In 2019, Brazil had a total of 214.9 million heads of cattle, 30.5% above that registered in 1999 (164.6 million heads).

The Brazilian meat sector is the second main export sector, but it lost participation in Brazilian agricultural exports between 2010 and 2016, from 21.4% to 19.9%. However, the value exported in this period increased from US$ 13.63 billion to US$ 14.21 billion, even with the fall in the average price of exported meat. In 2011, the average beef export price was US$ 4,881.74 per ton, and reached US$ 3,957.77 per ton in 2016 (Instituto Brasileiro de Geografia e Estatística [IBGE], 2019).

Among the Brazilian regions, the North region stands out in livestock production, with a herd of 49.6 million heads of cattle (23.1%) in 2019, the second largest in the country (IBGE, 2020). In this region, the state of Pará has the largest herd, with 20.9 million heads (42.1%), and in relation to the number of bovines in Brazil, the state contributed with 9.7% Given the significant participation of beef cattle, the state of Pará is the largest exporter of live cattle in Brazil since 2011, due to its productive potential and geographic location favorable to international marketing (Ministério da Agricultura, Pecuária e Abastecimento [MAPA], 2020), which contributes to the economy of municipalities in the state of Pará, generating employment, income and taxes.

In the state of Pará, extensive cattle-ranching predominates, based on deforestation and management of areas deforested with fire for the establishment of pastures. Beef cattle production is carried out on low-productivity cultivated pastures, with less than one head per hectare, which requires a significant amount of land, with a direct impact on the preservation of natural biodiversity (Hafla, Macadam, & Soder, 2013; IBGE, 2020). This production practice is carried out by deforestation and forest burning, contributing to increasing GHG emissions and causing environmental impacts (Hannah & Max, 2020).

Given the importance of cattle ranching for the economy of the country and the North region, especially the state of Pará, it is worth investigating which attributes of environmental sustainability define the activity of cattle ranching in the state of Pará. In this context, this study aimed to analyze the patterns of production in rural properties and develop a sustainability indicator for cattle farming in the micro-regions of the state.

Material and Methods

The research is exploratory and descriptive, with a quantitative approach, based on the isolation of key variables from the 2017 Agricultural Census (IBGE, 2019) for 22 micro-regions of the state of Pará. Variables were based on the recommendations of the new forest code Law 12651 (2012) and in studies by Melado (2007), Mattos, Santana, Pinto, Cardoso and Costa (2010), Alves, Almeida and Laura (2015), Santos, et al. (2017) and Global Roundtable for Sustainable Beef [GRSB] (2018).

Variables were obtained by counting the number of properties in which a certain characteristic was found and registered in the 2017 Agricultural Census, for example: in the case of the man manager variable, the value expresses the proportion between the number of properties managed by men in the municipalities forming the micro-region and the total number of properties in the micro-region. The variables obtained by the proportions express the level of a certain characteristic in each of the micro-regions. In these cases, we sought to relativize the weight of properties adopting sustainable land use practices, organizational management, infrastructure, access to information and communication technologies, and the social participation of these properties in the livestock production activity (Table 1).

Table 1
Definition of study variables

Variable	Description	Indicator characteristic
Literacy	Proportion of properties where the manager is literate	Efficient management indicator
Pasture area	Pasture area size, in ha	Livestock activity indicator
Electricity	Proportion of properties with access to electricity.	Infrastructure indicator
Man manager	Proportion of properties where management is conducted by man	Traditional management indicator
Woman manager	Proportion of properties where management is conducted by woman	Innovative management indicator
Social organization	Proportion of properties participating in associations, unions and social organizations	Social participation indicator
Pastures	Proportion of properties with pasture areas in their property	Livestock activity indicator
Conservation Practices	Proportion of properties in which conservation practices are carried out	Sustainable management indicator
Productivity	Ratio of the number of head of cattle and the pasture area (in ha) of the municipality	Competitive performance indicator
Water protection	Proportion of properties protecting water from lakes, rivers, stagnant (igapó) and streams (igarapé).	Environmental water footprint indicator
Animal health and supplementation	Proportion of properties using animal health protection and supplementation practices.	Social animal welfare indicator
Information and Communication Technology (ICT)	Proportion of properties in which information technologies are used in production or administration.	Digital Connectivity Indicator

The variables presented in Table 1 are conceptualized and described below:

Productivity: refers to the relationship between what is produced (cattle) and the means of production (Martha, Alves, & Contini, 2012);

Water protection: consists of the restoration of permanent protection areas and preservation of water courses to comply with the Forest Code (Amaral, Carvalho, Capanema, & Carvalho, 2012; Neven, 2015);

Man manager: historically, the management of rural property has been carried out by men, who must manage production and have a pluriactive action aimed at the development of agriculture and livestock production as a way to generate monetary income for rural families (Sousa & Silva, 2012);

Woman manager: women at the head of agricultural management are making a difference by showing greater efficiency in management by properly treating employees and providing guidance on good herd management practices and new technologies to provide health and welfare to animals, involving pasture systems with trees, genetics, feeding and productivity. They are gradually breaking the traditionalism of the farmer in search of improving the quality of the herd, productivity, social inclusion and environmental sustainability. In addition, they have a higher level of education, are younger and are connected to the market and the world of technological innovations (Spanevello et al., 2020);

Literacy: the level of education of the person who runs the rural properties is determining for the adoption of new production technologies and the management of production processes, generating greater efficiency in the activity. The lack of skills and competencies developed in the educational training process of producers reflects on the absorption of innovations and technologies, and compromises the competitiveness of agricultural activities (Mendes, Buainain, & Fasiaben, 2014);

Pastures: it is the main input of rural properties used for cattle ranching and must have good productivity, quality and longevity. Increasing the intensity of use of pasture areas, through the adoption of technologies, enables efficiency gains in the production process (Amaral et al., 2012);

Conservation practices: agronomic techniques used to raise pasture and herd productivity (heads/hectare), conserve and keep soil structure, mitigate erosion, siltation of streams, as well as water pollution (Amaral et al., 2012; Sambuichi, Oliveira, Silva, & Luedmann, 2012);

Information Technology: provides the use of technology for connectivity with the market and for digitizing activities, calculating results and producing indicators to monitor activity performance and guide decision-making. It enables the use of precision technology for mapping areas by Unmanned Aerial Vehicles (UAV), reading chips and, above all, obtaining market information, available technologies, acquiring knowledge, etc. (Mendes et al., 2014);

Electric energy: fundamental resource for the adoption of advanced management techniques, production processing and property management. With electricity, it is possible to access hardware and software, and electronic equipment necessary for the production process, commercialization and the search for information on the bovine market (Pierozzi, Souza, Torres, Oliveira, & Queiros, 2014);

Social organization: organized action of farmers in cooperatives, unions, federations and societies linked to livestock production that contribute to obtaining information, technologies and process, product and management innovations, access to markets, and that enable coordination and increased efficiency governance of the livestock production chain (Santana et al., 2019). The economic gain promoted by governance in the chain comes from the increased efficiency of the production system resulting from the exchange of information on sustainable production practices, the reduction in transaction costs and opportunistic behavior (Zylbersztajn, Neves & Caleman, 2014);

Animal health and supplementation: The health and feeding of animals, in compliance with the legislation to vaccinate, supply nutrient deficiencies, provide comfort to animals with shade (trees), quality water and good management practices increase productivity and facilitate access to the market.

The exploratory factor analysis (EFA) technique is essential in studies that rely on a high number of quantitative and qualitative variables, which would tend to cause serious statistical problems of multicollinearity and, therefore, prevent them from capturing its influences on the phenomenon studied (Santana, 2020). In this case, the set of variables defined in a relativized way for the micro-regions of the state of Pará aim to explain the influence of the use of technologies and procedures related to pasture, water and herd management.

EFA has the ability to summarize the set of dispersed information into a smaller subset of variables or factors capable of explaining the phenomenon studied without significant loss of information (Santana, 2020). In EFA, each factor is defined by a vector of significant factor loadings, associated with the ability of each variable to explain the factor and the latter to explain a portion of the total variance of the data. Therefore, it is possible to associate these dimensions to situations experienced by the arrangement of characteristics associated with each variable, according to their alignment with latent dimensions such as management, productivity, social participation, animal welfare, which would not be feasible through the analysis of descriptive statistics or traditional econometric models (Santana, 2007). For this, the variables were standardized via correlation matrix, where the highest correlations were separated to identify the latent dimensions that can present the necessary information to understand the phenomenon studied and respond to the objective of developing the indicators.

In an exploratory way, the Varimax orthogonal rotation method was used, identifying the underlying predictors. For the extraction of the factors, the methods of principal components analyses were used, which cover the total data variance. After extracting the factors and estimating the factor scores, the performance indicators and activity concentration by micro-region were built considering the algebraic structure developed by Santana (2007), in which the index represents the linear combination of factors for each of the dimensions, weighted by the proportion of the total variance explained by each of the factors, algebraically the index is defined by Equation 1.

$$ID_j = \sum_{i=1}^{K} \left(\frac{\theta_i}{\sum \theta} \cdot FP_{ij} \right) \tag{1}$$

Where:

ID = Performance index in micro-region j.

θ_i = Percentage of variance explained by factor i.

K = number of factors selected by factor i.

FPji = is the standardized factorial score i, by the Range method, of micro-region j.

With the scores of the factors extracted from the application of EFA, the performance indicator constructed with the application of Equation 1, and the variable pasture area, the statistical technique of linear correlation analysis was applied using the Pearson model (Hair, Babin, Money, & Sampouel 2009), with the aim of evaluating the degree and direction of the linear association between these variables.

As sustainability indicators vary between zero and one, four strata defined as: Critical (0.001 to 0.250); Alert (0.251 to 0.500);

Acceptable (0.501 to 0.750); Ideal (0.751 to 1.000), according to the method developed by Martins and Cândido (2012). These intervals were used to generate representative maps for each of the indicators.

The data sample was adequate for the use of EFA as indicated by the Kaiser-Meyer-Olkin (KMO) and Bartlett tests. The KMO measure of sampling adequacy was 0.669 with a significance level of less than 0.01. Bartlett's test of sphericity of 259,424 with 55 degrees of freedom showed a highly significant correlation between the survey items. The determinant of the correlation matrix was different from zero (1.485 x 10^7). Commonality values were above 0.500, as desired, and show the explanatory power of the variable by the factors. The factor loading or correlation matrix between each variable and the factor showed high significance for all associated variables in the definition of the factors.

Results and Discussion

The state of Pará has 144 municipalities that develop livestock production in agricultural properties using different management practices, associated with the use of information technology and communication (ICT), to increase production efficiency and the degree of sustainability of the activity. In these terms, it is worth highlighting the wide range between the maximum and minimum values for the variables pasture area, productivity, conservation practices and the proportion of properties with pasture (Table 2).

The main descriptive measures calculated were: minimum, maximum, mean, standard deviation and coefficient of variation (CV) of the analyzed series. It is noteworthy that the highest CV was the pasture area. The presence of an outlier for the Redenção micro-region was detected in the variable ICT, and the mean of the variable was imputed as a mechanism for eliminating the outlier. In fact, the variables used in the estimation of the main components to be identified as factors, based on the correlation matrix between all the studied variables, the atypical effects lose importance, since all correlations vary ± 1 (Santana, 2007).

Data in Table 3 present the values for each of the variables by micro-region, in which the largest pasture area was observed in the municipality of São Félix do Xingu (2,499,031 ha), followed by Altamira (1,899,980 ha), Redenção (1,425,026 ha), Conceição do Araguaia (1,348,757 ha) and Tucuruí (1,295,096 ha), which together represented 62.1% of the total 13,628,026 ha pasture areas accounted for by the 2017 Agricultural Census It should be noted that 54.3% cattle herd in the state of Pará (14,349,553), in 2017, was found in these five municipalities. Livestock farming is a representative activity in the state of Pará (IBGE, 2019), and is present in its entirety in the micro-regions of the state of Pará, with the exception of the municipalities of Belém, Limoeiro do Ajuru, Marituba, São Sebastião da Boa Vista, Salinópolis and Terra Alta.

Table 2
Descriptive Statistics of the variables used in the study

Variable	Minimum value	Maximum value	Mean value	Standard deviation	CV (%)
Literacy	0.522	0.875	0.790	0.086	10.83
Pasture area (ha)	435	2499031	619455.60	697545.10	112.60
Electricity	0.368	0.897	0.674	0.132	19.64
Man manager	0.641	0.857	0.794	0.052	6.50
Woman manager	0.142	0.358	0.203	0.052	25.51
Social organization	0.084	0.229	0.151	0.050	32.87
Pastures	0.004	0.461	0.200	0.152	76.01
Conservation Practices	0.006	0.090	0.038	0.024	64.43
Productivity	0.001	1.144	0.390	0.309	79.13
Water protection	0.256	0.658	0.418	0.122	29.21
Animal health and supplementation	0.102	0.804	0.446	0.249	55.83
Information and Communication Technology (ICT)	0.153	0.256	0.181	0.027	14.73

Source: Agricultural Census (IBGE, 2019).

The municipalities of Tucuruí (1.143) and Redenção (0.937) showed higher productivity, due to better quality herd, use of genetic improvement technology and dissemination through the sale of animals, semen and embryos to local farmers, which is a requirement of slaughterhouses under the Federal Inspection System (SIF) for the acquisition of animals for slaughter. Opposite to the better quality of the herd are the micro-regions Guamá (0.001) and Furos de Breves (0.003), with productivity close to zero. In these municipalities, livestock production is developed in small areas in the extensive raising and rearing system on planted pastures and native pastures with dual purpose herd, which increases the longevity of the production cycle and, in turn, decreases productivity (Santos et al., 2018). In this sense, extensive and low-productivity cattle farming entails several risks (legal, reputational, commercial and operational) for companies in the sector and the exposure of investors to additional risks, caused by unsustainable practices, on the part of producers, which threatens the business environment (World Wildlife Fund [WWF], 2017).

In relation to properties that protect the water on their land, the high proportion observed in the micro-regions of Itaituba (0.657) and Tucuruí (0.611) reduces the environmental pressures on deforestation of public forest areas, especially in areas of permanent protection adjacent to rivers and streams. Among those that least protect water sources, properties in the micro-regions Bragantina (0.269) and Santarém (0.256) stood out, due to the observation and action of environmentalists.

Table 3
Variable values per microregion

Micro-region	Variables											
	1	2	3	4	5	6	7	8	9	10	11	12
Almeirim	0.738	83.205	0.544	0.835	0.165	0.226	0.232	0.007	0.139	0.443	0.378	0.192
Altamira	0.803	1.899.980	0.807	0.833	0.165	0.093	0.260	0.013	0.486	0.567	0.601	0.173
Arari	0.817	322.292	0.507	0.738	0.261	0.138	0.076	0.039	0.143	0.281	0.183	0.156
Belém	0.872	1.171	0.703	0.641	0.358	0.174	0.004	0.062	0.188	0.276	0.186	0.205
Bragantina	0.748	96.284	0.738	0.812	0.185	0.105	0.106	0.044	0.593	0.269	0.398	0.163
Cametá	0.832	15.639	0.737	0.766	0.234	0.220	0.019	0.070	0.204	0.333	0.217	0.164
Castanhal	0.806	27.187	0.738	0.723	0.276	0.210	0.016	0.090	0.395	0.329	0.212	0.153
Conceição do Araguaia	0.846	1.348.757	0.715	0.816	0.181	0.134	0.461	0.021	0.021	0.496	0.742	0.212
Furo de Breves	0.613	435	0.520	0.796	0.203	0.184	0.015	0.077	0.003	0.378	0.102	0.158
Guamá	0.723	614.252	0.626	0.814	0.184	0.098	0.155	0.046	0.001	0.368	0.306	0.160
Itaituba	0.823	738.260	0.651	0.833	0.166	0.191	0.307	0.024	0.370	0.658	0.723	0.186
Marabá	0.793	863.262	0.842	0.806	0.190	0.141	0.328	0.012	0.755	0.488	0.694	0.186
Óbidos	0.841	156.044	0.500	0.798	0.193	0.228	0.268	0.017	0.507	0.354	0.461	0.163
Paragominas	0.796	766.401	0.706	0.830	0.166	0.160	0.349	0.037	0.639	0.485	0.634	0.194
Parauapebas	0.838	799.357	0.869	0.812	0.185	0.152	0.338	0.028	0.330	0.350	0.723	0.187
Portel	0.522	23.255	0.368	0.857	0.142	0.087	0.021	0.060	0.055	0.549	0.104	0.158
Redenção	0.848	1.425.026	0.897	0.831	0.164	0.129	0.387	0.013	0.938	0.404	0.743	0.256
Salgado	0.867	15.902	0.608	0.734	0.254	0.109	0.025	0.054	0.278	0.328	0.157	0.163
Santarém	0.859	450.154	0.610	0.753	0.249	0.229	0.222	0.016	0.510	0.256	0.478	0.171
São Feliz do Xingu	0.875	2.499.031	0.695	0.850	0.147	0.084	0.364	0.006	0.654	0.611	0.804	0.234
Tomé-açu	0.747	187.034	0.659	0.768	0.230	0.108	0.068	0.052	0.232	0.371	0.228	0.163
Tucuruí	0.784	1.295.096	0.792	0.832	0.165	0.118	0.371	0.043	1.144	0.611	0.737	0.188

Variable code: (1) Literacy, (2) Pasture area, (3) Electricity, (4) Man manager, (5) Woman manager, (6) Social organization, (7) Pastures (8) Conservation practices, (9) Productivity (10) Water protection, (11) Animal health and supplementation, (12) Information and Communication Technology (ICT).

In the set of conservation practices, in Castanhal (0.090) and Furo de Breves (0.077) the proportions did not reach 0.100 in the micro-regions of the state of Pará. This results from the use of the Green Municipality Program with extension to farms with technology (crop-livestock and crop-livestock-forest) for the restoration of degraded pastures and control of illegal logging (Maneschy, Santana, & Veiga, 2010). The micro-regions of Almeirim (0.007) and São Félix do Xingu (0.006) presented the lowest proportions of properties with conservation practices, as they have large farms and low-sustainability management of pastures. These pastures, in the vast majority of rural properties, are not fertilized, and there is insignificant control of pests such as leafhopper, weed control by herbicides and fire, and, in some cases, the use of animals on pasture in number and time is not efficient. With this, pastures degrade more quickly and induce the opening of new forest areas, as pasture restoration tends to have a higher cost than the formation of new pasture (Santana et al., 2019).

Among the 22 micro-regions in the state of Pará, São Félix do Xingu stood out for its high concentration of herds and productive potential. In this micro-region, according to data from IBGE (2019), cattle farming has a total of 2,557,763 heads, for 10,731 agricultural properties. Among these, 9,110 had planted pastures in good condition, which represents 9.37% of the state. There were 16,535 jobs related to the activity in this micro-region, which corresponds to 5.86% of the total for the state. In these properties, there was a mostly white population that can read and write, aged between 30 and 60 years. It is also worth mentioning 10,169 agricultural properties with ownership of their own land, representing 4.12% for the entire state.

The EFA by principal components proved to be adequate to identify the attributes of environmental sustainability that define cattle ranching in the state of Pará. Three factors were extracted and together explained 80.8% total data variability (Table 4). The first factor explained 48.1% total variance. The variables woman manager and conservation practices had a negative sign, inversely related to the other variables in the explanation of the factor, in which these variables move towards counterbalancing the inefficient management and use of traditional pasture, herd and water management practices, configuring a process of transition from traditional male management to a combination with female management of greater efficiency and connectivity with the other links in the chain and with the market. The factor was called Transition Management.

The correlation structure of the variables with the first factor showed that the management of the herd, pastures and care with water sources and preservation of legal reserve areas and permanent protection areas, as well as progress in the regularization of labor used are emerging actions to frame the livestock production activity within the minimum parameters of sustainability. These results corroborate Escobar (2020).

Table 4
Factorial matrix of the dimensions of environmental sustainability in cattle ranching, state of Pará

Variables	Factors			Commonality
	1	2	3	
Literacy	-0.316	0.784	0.370	0.851
Electricity	-0.091	0.849	-0.256	0.795
Man manager	0.955	0.023	-0.174	0.943
Woman manager	-0.952	-0.037	0.178	0.940
Social organization	-0.238	-0.091	0.840	0.771
Pastures	0.660	0.682	0.169	0.931
Conservation Practices	-0.612	-0.517	-0.348	0.763
Productivity	0.203	0.719	-0.184	0.592
Water protection	0.077	0.165	-0.236	0.680
Animal health and supplementation	0.581	0.784	0.071	0. 956
Information and Communication Technology (ICT)	0.297	0.729	0.018	0.620
Explanation of variance (%)	48.1	22.8	9.5	80.4

Factor two explained 22.8% total variance, highlighting the variables: productivity, literacy, pasture, ICT, electricity and animal health and supplementation with positive and high signs. The factor was called Technical Productive Efficiency, because it includes digital management, connectivity to the market for accessing and using information and closing deals, quality production and higher carcass yield and total production system productivity. This dimension, associated with the effects of the previous dimension, moves towards modernization and transformation to participate in inclusive and sustainable value chains of livestock products from the state of Pará, adding value to the product that translates into benefits for the consumer and for the producer (Souza et al., 2017).

The third factor explained 9.5% total variance and was explained only by the social organization variable, and was called Organization Participation. According to Santana et al. (2019), social participation makes it possible to obtain information on production practices, access to credits and markets in order to facilitate coordination and increase the efficiency of governance in the livestock production chain.

Based on the scores of each of the three latent dimensions that emerged from the application of the EFA, four indicators were developed, three referring to each of the dimensions: Transition Management Indicator (TMI), Sustainable Competitiveness Indicator (SCI) and Organization Participation Indicator (OPI) (Table 5). The fourth indicator developed was called the Traditional Performance Indicator (TPI) and calculated according to Equation 1 presented in the methodology.

Table 5
Results of the sustainability indicators for livestock production, state of Pará

Micro-region	TMI	SCI	OPI	TPI
Almeirim	0.953	0.385	0.947	0.876
Altamira	0.835	0.676	0.147	0.779
Arari	0.431	0.416	0.518	0.301
Belém	0.001	0.696	0.452	0.001
Bragantina	0.578	0.559	0.073	0.451
Cametá	0.393	0.496	0.531	0.305
Castanhal	0.227	0.523	0.359	0.125
Conceição do Araguaia	0.858	0.698	0.567	0.880
Furo de Breves	0.652	0.151	0.360	0.362
Guamá	0.704	0.371	0.194	0.499
Itaituba	0.960	0.587	0.663	0.941
Marabá	0.750	0.786	0.323	0.778
Óbidos	0.770	0.490	1.000	0.755
Paragominas	0.829	0.665	0.418	0.810
Parauapebas	0.675	0.761	0.440	0.708
Portel	1.000	0.001	0.001	0.577
Redenção	0.750	1.000	0.262	0.877
Salgado	0.335	0.526	0.235	0.216
Santarém	0.526	0.620	0.964	0.572
São Feliz do Xingu	0.962	0.828	0.261	1.002
Tomé-açu	0.499	0.454	0.128	0.326
Tucuruí	0.827	0.801	0.032	0.816
Mean	0.660	0.568	0.403	0.589
Variance	0.069	0.051	0.084	0.084

TMI: Transition Management Indicator; SCI: Sustainable Competitiveness Indicator; OPI: Organization Participation Indicator; TPI: Traditional Performance Indicator.

The mean TMI was the highest among the calculated indicators and 13 (59%) of the 22 micro-regions had an index higher than the mean value. This evidences a cattle production management process based on sustainable practices, with emphasis on the micro-regions of Portel (1,000), São Félix do Xingu (0.962), Itaituba (0.960), Almeirim (0.953), Conceição do Araguaia (0.858), Altamira (0.835), Paragominas (0.829), Tucuruí (0.827), Óbidos (0.770), Marabá (0.750) and Redenção (0.750). The micro-regions with index below the mean were Furo de Breves (0.652), Bragantina (0.578), Santarém (0.526), Tomé-Açu (0.227), Arari (0.431), Cametá (0.393), Salgado (0.335) and Castanhal (0.227), indicating that cattle ranching is still predominantly developed using traditional pasture management.

Figure 1 for the TMI shows that 77.7% (17) of the micro-regions were classified with an acceptable or ideal index, indicating that, in most livestock-producing properties in these territories, the management of cattle ranching presented aspects related to leadership of men in management, in which women also stood out, the practices of production and protection of water are important for the restoration of areas of permanent protection and preservation of water courses. This indicates a low range of environmental sustainability indicators.

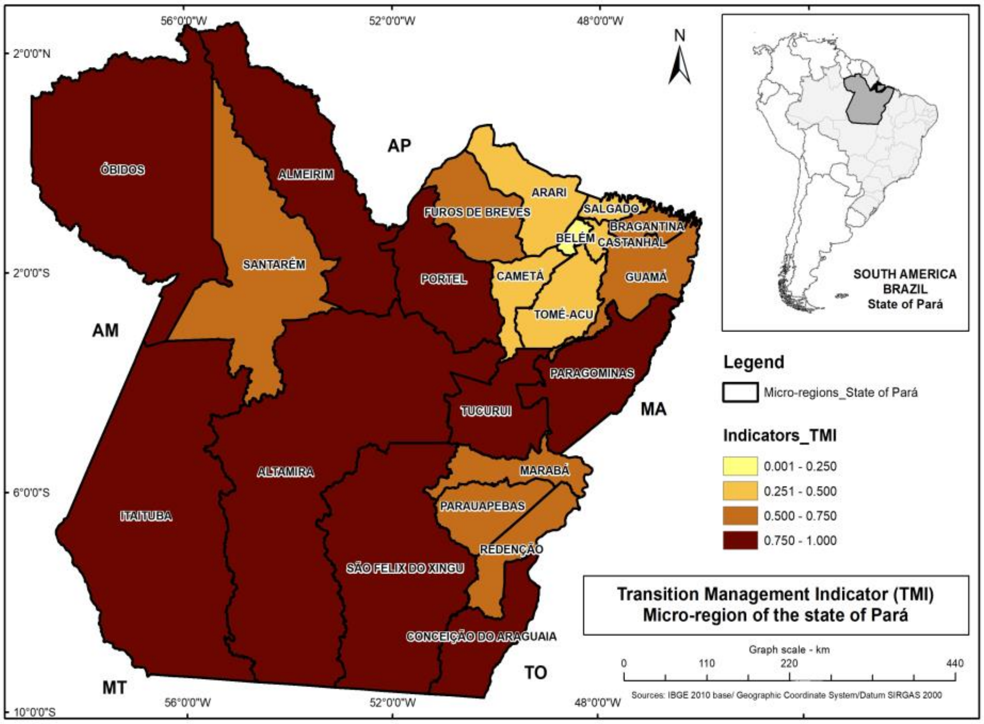

Figure 1. Transition Management Indicator (TMI).

Considering the SCI, 50% micro-regions had an index below the mean. The highest indices were found for Redenção (1.000), São Félix do Xingu (0.828), Tucuruí (0.801), Marabá (0.786) and Parauapebas (0.761), all classified in the ideal index category, as can be seen in Figure 2. In these micro-regions, livestock production is carried out in properties equipped with infrastructure with electricity, animal handling practices, use of ICT, in addition to literate managers and higher herd productivity. Among the micro-regions with an indicator below the mean, Furo de Breves (0.151) and Portel (0.001) were classified as having a critical SCI index.

The SCI showed that micro-regions classified as acceptable or ideal are in transition process of technological modernization of the cattle ranching activity, aiming to participate in the inclusive and sustainable value chains of livestock products of the state of Pará, adding value to the product that translates into benefit for the consumer and for the producer (Souza et al., 2017).

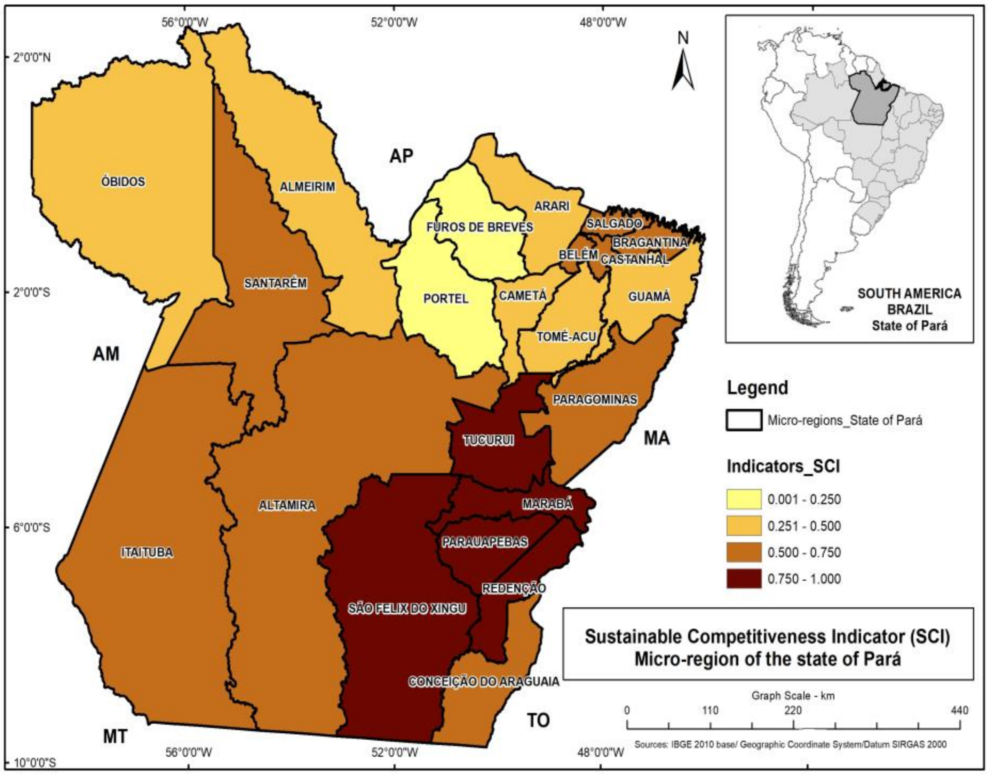

Figure 2. Sustainable Competitiveness Indicator (SCI).

The OPI showed the lowest mean among the calculated indicators and the greatest variability among micro-regions, in which 12 out of 22 micro-regions had an indicator below the mean. The worst indices were observed for Salgado (0.235), Guamá (0.194), Altamira (0.147), Tomé-açu (0.128), Bragantina (0.073), Tucuruí (0.032) and Portel (0.001), these micro-regions were classified as critical OPI. The micro-regions with the best indicators, in the category of ideal OPI index, were located in the western region of the state of Pará, especially Óbidos (1.000), Santarém (0.964) and Almeirim (0.947), as illustrated in Figure 3.

The OPI reflects the participation of producers in local and national organizations to access knowledge, expand market share, access credit and influence the implementation of policies in favor of livestock. This is the way to achieve transparency and increase the efficiency of the governance of the Pará livestock production chain.

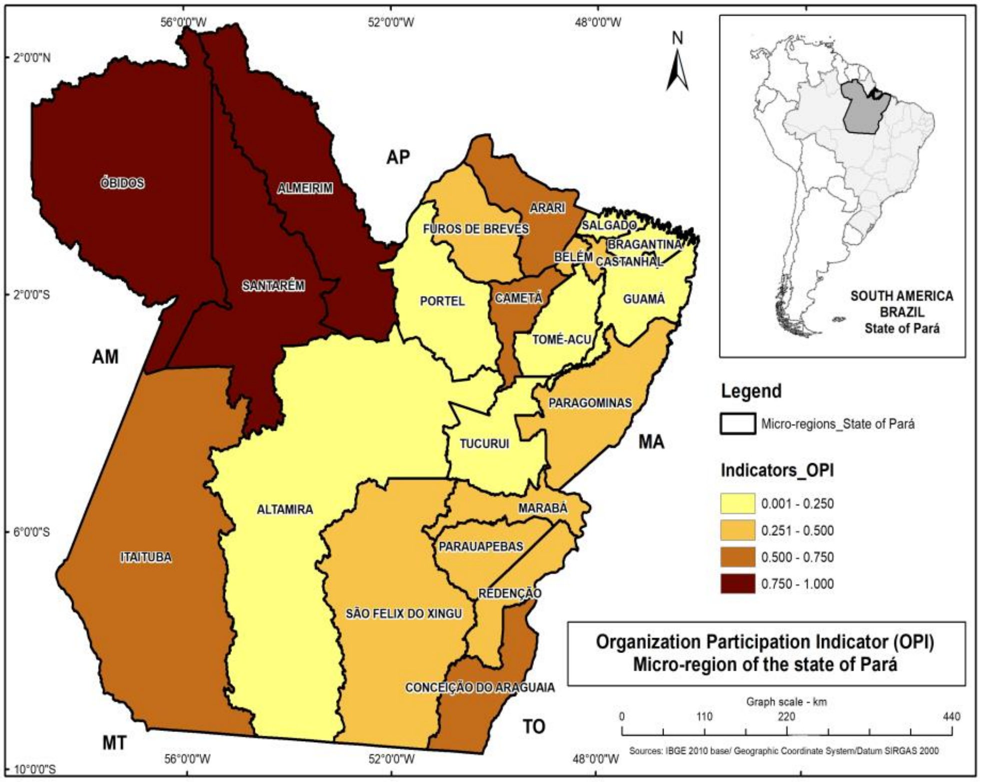

Figure 3. Organization Participation Indicator (OPI).

The TPI shows that 50% micro-regions presented values above the mean, especially São Félix do Xingu (1,000), Itaituba (0.941), Conceição do Araguaia (0.880), Redenção (0.877), Almeirim (0.876), Tucuruí (0.816), Paragominas (0.810), Altamira (0.779), Marabá (0.778) and Óbidos (0.755). As the TPI was calculated using Equation 1, and the variance explained by the TMI or SCI adds up to 87%, the characteristics of these two indicators influence the result of the TPI, in which high values of the two indicators are related to high TPI values. In case of one of TMI or ICS values is very low, the result will be a low TPI value, as is the case of the Castanhal micro-region, with a TMI of 0.227, SCI of 0.523, and the TPI reached 0.125. It should be noted that micro-region of Castanhal has a small proportion of the area with pastures (0.016) and the proportion of properties with conservation practices is very low (0.090), central aspects for the critical level of the TPI, as can be seen in Figure 4.

The result of the TPI explains, in part, why extensive cattle ranching, which uses forest deforestation and burning to expand pasture areas (Barreto, 2017), combined with the low productivity of the productive system (Santos et al., 2018), increases in the state of Pará, despite the great impact on forest destruction.

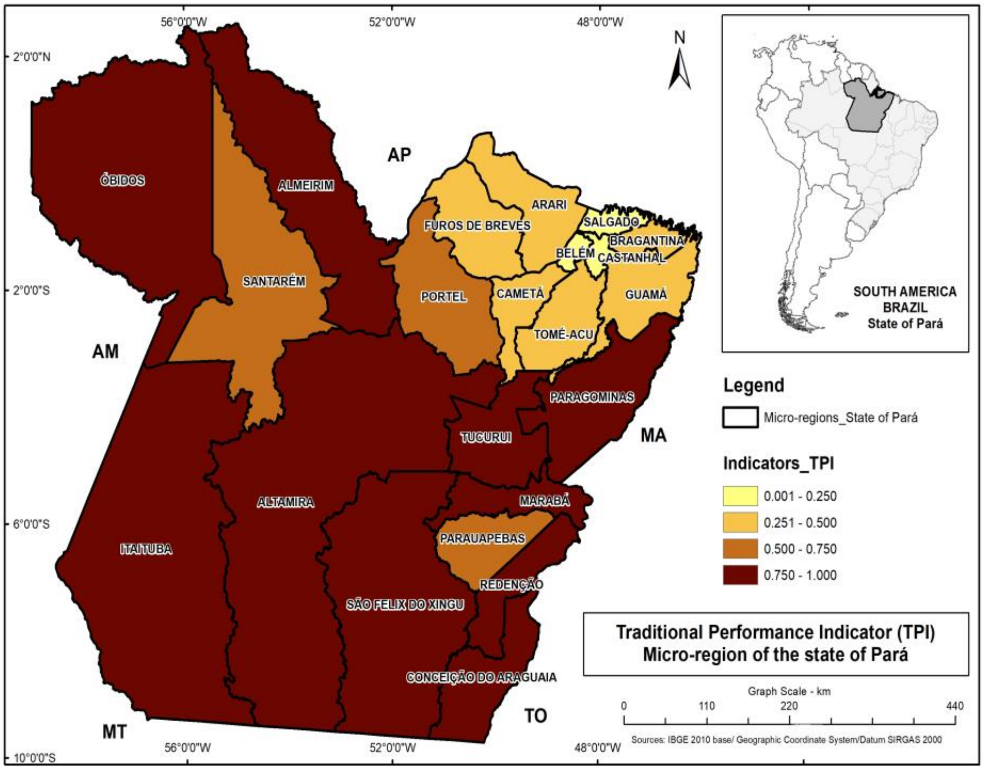

Figure 4. Traditional Performance Indicator (TPI).

The linear correlation between the sustainability indicators and the pasture area of the micro-regions showed a positive and high association at 0.702 between the pasture area and the TPI index, with a statistical significance of 0.01, indicating that high values of the pasture area are associated with high TPI values. This high association, in part, is related to extensive livestock production in the Amazon, which is developed in all sizes of property. Indeed, the main environmental risks of livestock farming to achieve environmental sustainability arise from changes in land use, resulting from deforestation and the conversion of natural ecosystems into cultivated areas, and from the degradation of cultivated areas, caused by inadequate management practices (Sambuichi et al., 2012; Rajão et al., 2020).

In this sense, the biggest challenge for cattle producers in the Legal Amazon has been to adapt their production systems to the current environmental requirements that created a previously non-existent environmental liability for local producers, as they were charged by the government to deforest up to 50% of their properties, as a demonstration that their lands were productive. Due to this environmental liability, Rivero et al. (2009) indicated the livestock production activity as the main responsible for deforestation in the Brazilian Amazon.

Conclusion

The strong and positive correlation between the Traditional Performance Indicator (TPI) and pasture areas indicates that the larger the size of the pasture area, the higher the level of the indicator in the micro-regions evaluated in the state of Pará, which responds to the problem of research enunciated in the introduction, that is, which attributes of environmental sustainability define the cattle ranching activity in the state of Pará. What persists in these micro-regions are production practices in which men lead the management, but women are competent managers and can reverse this situation; water protection practices are present on the properties, however, in precarious conditions, and conservation practices are little used.

In the micro-regions that make up the state of Pará, there is high heterogeneity in the levels of management practices employed by properties with livestock production activity, and which are part of the initial link in the value chain of livestock farming in the state of Pará. Among them, extensive livestock farming stands out, with low productivity, with little use of sustainable practices and information and communication technologies. In this context, the activity coexists with high risks in the business environment.

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