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Typologies and Spatialization of Agricultural Production Systems in Rondônia, Brazil: Linking Land Use, Socioeconomics and Territorial Configuration

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Abstract: The current Amazon landscape consists of heterogeneous mosaics formed by interactions between the original forest and productive activities. Recognizing and quantifying the characteristics of these landscapes is essential for understanding agricultural production chains, assessing the impact of policies, and in planning future actions. Our main objective was to construct the regionalization of agricultural production for Rondônia State (Brazilian Amazon) at the municipal level. We adopted a decision tree approach, using land use maps derived from remote sensing data (PRODES and TerraClass) combined with socioeconomic data. The decision trees allowed us to allocate municipalities to one of five agricultural production systems: (i) coexistence of livestock production and intensive agriculture; (ii) semi-intensive beef and milk production; (iii) semi-intensive beef production; (iv) intensive beef and milk production, and; (v) intensive beef production. These production systems are, respectively, linked to mechanized agriculture (i), traditional cattle farming with low management, with (ii) or without (iii) a significant presence of dairy farming, and to more intensive livestock farming with (iv) or without (v) a significant presence of dairy farming. The municipalities and associated production systems were then characterized using a wide variety of quantitative metrics grouped into four dimensions: (i) agricultural production; (ii) economics; (iii) territorial configuration, and; (iv) social characteristics. We found that production systems linked to mechanized agriculture predominate in the south of the state, while intensive farming is mainly found in the center of the state. Semi-intensive livestock farming is mainly located close to the southwest frontier and in the north of the state, where human occupation of the territory is not fully consolidated. This distributional pattern reflects the origins of the agricultural production system of Rondônia. Moreover, the characterization of the production systems provides insights into the pattern of occupation of the Amazon and the socioeconomic consequences of continuing agricultural expansion.

Keywords: Amazon; land use; multidimensionality; socioeconomic; TerraClass

1. Introduction

The colonization of the Brazilian Amazon has directly led to a new geography, with significant impacts on the natural environment and regional development [1,2]. The waves of settlement produced a strong integration of local livestock supply chains with national and international markets, further reinforcing and incentivizing the process of occupation [3–5]. However, the occupation of land has been characterized by different systems of production that generate different costs and benefits for the economy, socioecological systems and farming [6–9]. Such differences in production originate from different land use systems and/or the different techniques adopted for the same land use in different production systems.

An in-depth knowledge of regional geography is therefore fundamental to understand the spatial distribution and evolution of agricultural supply chains, in order to assess the impact of current policies and future actions [10]. Knowledge of the effects of shifting land use is equally important in the search for sustainable solutions for impacted rural communities [11,12], since themes such as climate change, food security, biodiversity and energy sources will also be strongly influenced by regional geographies [13].

Spatial analysis of socioeconomic data is an important element in the construction of rural development indices. Such indices lack robustness if they are based on an insufficient number of metrics/indicators and, ideally, should incorporate measures of land use and landscape characteristics [14]. More generally, the analysis of spatial patterns of socioeconomic indicators contributes to an understanding of the spatial variations of the territory [15].

Agronomic geography concerns the identification and analysis of spatial variation in agricultural practices, uncovering the many factors that contribute to this spatial distribution [16–18]. The formation of different agricultural production regions, within territorial dynamics linking geography and economics [18,19], highlights the importance of studying geographical development at a regional scale.

Previous studies analyze socioeconomic data from the demographic census and/or agricultural census in the context of land use changes in the Amazon [20,21] or to explain poverty among agricultural producers in Brazil [22]. Others employ landscape analysis techniques to study land use changes [23]. In this paper, we explore how spatial analysis of land use and socioeconomics attributes can contribute to the discovery of patterns of distribution of agricultural system productions. Our hypothesis is that it is possible to identify the predominant systems of production in each municipality based on the percentage of annual crop, clean pasture, and dairy cows.

With the aim of contributing to geographical knowledge of agricultural production systems in Rondônia State, Brazil, the objectives of this article are to identify the predominant systems at a municipal scale, and to characterize these systems using a wide variety of quantitative metrics grouped into four dimensions: (i) agricultural production; (ii) economics; (iii) territorial configuration, and; (iv) social characteristics.

2. Materials and Data Preparation

2.1. Study Area

The Brazilian State of Rondônia covers 237,590 km^2 and is currently divided into 52 municipalities. The state has its origins in the Guaporé territory (formed from parts of Amazonas and Mato Grosso States) that was created in 1943 (Federal Decree No. 5.912, 13 September 1943). In 1956, this territory was renamed Rondônia and was officially converted into a state in 1981 (Complementary Law No. 41, 22 December 1981). Significant colonization of Rondônia began in the early 20th century in response to the growth of latex extraction in the Amazon and facilitated by the construction of the Madeira-Mamore railway. The construction of the BR-364 highway in the 1970s linked the capital, Porto Velho, to the southcentral region of the state and integrated local supply chains with the regional and global market [24,25]. This process of occupation intensified throughout the century, reaching its peak in the 1980s [26,27].

During the 1970s and 1980s, the National Institute of Colonization and Agrarian Reform (INCRA), with the support of national and international banks and (national and international) funding agencies, facilitated the settlement of tens of thousands of families of migrants in Rondônia. The settlement served the dual purpose of supporting the Brazilian Government's Amazon occupation policy to relieve agrarian conflicts in other regions of Brazil, and also to facilitate the integration of the Amazon into Brazilian economic space [10,26,28–30].

This intense process of agricultural colonization was mainly held by small farmers in settlement projects along the state's open road system [24,25]. Inevitably, this process led to profound changes in land cover, especially the conversion of native forest to agricultural land: Rondônia has experienced the third highest percentage reduction of original forest cover in the Brazilian Legal Amazon [31]. This process of configuration/reconfiguration of territory gave rise to regions that specialized in certain production chains, such as the establishment of a grain-producing region in the south of Rondônia [32]. Data from the TerraClass 2008 project confirm such specialization, demonstrating that in 2008 the deforested areas in Rondônia were mainly occupied by pastures (79%), followed by secondary vegetation (16%) and annual (crop-based) agriculture (2%) concentrated in the south of the state [33].

2.2. Metrics to Characterization of Production Systems

In order to perform the regional analysis and further characterize the agricultural production systems, a variety of quantitative metrics (full specifications in Table A1 in Appendix A) were applied at the municipal level. To facilitate analysis and interpretation, these metrics were grouped into four dimensions; (i) agricultural production; (ii) economics; (iii) territorial configuration, and; (iv) social characteristics.

2.2.1. Dimension 1: Agricultural Production

We used data from the survey of municipal agricultural production, coordinated by the Brazilian Institute of Geography and Statistics (IBGE) [34] to evaluate agricultural production. Data was retrieved on production of beef and milk cattle, planted area of coffee, and income of the top five annual crops of the state (rice, beans, cassava, corn and soybeans). It should be noted that several other land uses (e.g., annual and perennial crops as well as the economic exploitation of other animals) occur in Rondônia. However, the contribution of cattle (beef and milk) and the above-listed crops represent more than 93% of total agricultural income in the state. For agricultural income, the sum of the value of agricultural production and livestock, available in the literature, was considered [35]. The selected agropastoral activities were present in all municipalities with the exception of soybean production. Although soybean is only grown in 12 out of 52 municipalities, it has a relatively high cultivated area and, where present, makes a significant contribution to the local economy [34,35].

To complement the original IBGE data [34], further metrics were calculated that indicate livestock productivity in relation to pasture area (derived from the TerraClass data) and the number of animals per municipality (data from IBGE). For crops, the financial income generated by each major crop to local agricultural economy was recorded [34], as was the percentage of area occupied by coffee in relation to the total production area of each municipality.

2.2.2. Dimension 2: Economics

2.2.2.1. Gross Domestic Product (GDP)

We used Gross Domestic Product (GDP) as a metric to study the impact and economic contribution of different land uses on the local economy. GDP is the sum of monetary values of all goods and services produced in a given region over a given period. It consists of the gross value added by agricultural activities (Agricultural GDP), the gross value added of industry (Industrial GDP), and gross value added by services (Services GDP).

Municipal GDP data for the years 2000 (T1) and 2010 (T2) were retrieved from the IBGE database [34]. GDP was divided into Agricultural GDP and total GDP for each municipality to allow calculation of the indirect contributions of the agricultural sector (e.g., sale of fuel, services, *etc.*). These indirect contributions are not included in the agricultural GDP, but they may be indirectly related to the agricultural production chain and contribute to total GDP.

GDP data is available in the form of an absolute monetary value for the entire municipality. Within each municipality, agricultural production only takes place in deforested areas (the minor exception being timber production or non-timber forest products). Thus, it may be possible to, at least partially, infer the production efficiency of different land use systems by generating new metrics that take into consideration the deforested area of each municipality (GDP per km^2 deforested and Agricultural GDP per km^2 deforested). We also estimated the GDP per capita for each municipality and the Agricultural GDP per capita for the rural zone.

2.2.2.2. Agricultural Credit

Brazil's Central Bank produces a statistical yearbook of rural credit which contains information on the number of operations and the resources available for rural credit operations for each Brazilian municipality [36]. Annual data from this dataset were used for the years 2000 to 2010. A statistical relationship was then sought between the amount of credit disbursed and the deforested area at the municipal scale. By dividing the total amount of rural credit in each year by the deforested area in each municipality for that year, we were able to calculate the average value (in R$) of rural credit per km^2 deforested.

2.2.2.3. Logistics

To study the relationship between agricultural production and transport infrastructure, data was obtained for the general road network for Rondônia from the Amazon Protection System—SIPAM [37]. We used this data to calculate a metric of municipal road density by dividing the total perimeter of roads in a municipality by the total area of that municipality. We adopted a similar approach to assess hydrographic network: data was retrieved from SIPAM [37] and municipal density of the network was calculated by dividing the total perimeter of the hydrographic network by the total area of the municipality.

2.2.3. Dimension 3: Territorial Configuration

Landscapes are the result of interactions between human societies and the space that surrounds them [38]. Landscape analysis is a way to study the intrinsic spatial heterogeneity within the natural environment [39], revealing territorial configurations. In this study, we apply metrics to allow the description of landscapes' configuration and composition [40]; such metrics have been commonly used to study deforestation and agricultural landscapes [41–44]. These metrics can also be used to identify and quantify spatial heterogeneity, providing a key link between patterns and processes [45]. Three types of territorial configuration data were analyzed: (i) deforested area [31]; (ii) land use distributions [33]; and (iii) environmental conservation units [46].

2.2.3.1. The Amazon Deforestation Monitoring Project (PRODES)

The Amazon Deforestation Monitoring Project (PRODES) [31] has been run by the Brazilian National Institute of Space Research (INPE) since 1988. The project produces annual maps of deforestation in the Brazilian Legal Amazon, and is able to identify deforested areas larger than 6.25 ha. We used these data in their original format of annual deforestation polygons. We also evaluated the full total area deforested, disregarding the date of occurrence.

2.2.3.2. TerraClass

Land use and land cover data are essential for understanding landscape configuration and for revealing the organizational strategies and patterns of agricultural production [47,48]. TerraClass data [33] with a spatial resolution of 30 m allows for both regional level and municipal level analysis of land use and land cover dynamics. TerraClass 2010 is available and contain the following classes: deforestation up to 2010; crop area (annual); unobserved area; urban area; mining; mosaic occupations; other areas; pasture with exposed soil; clean pasture; "dirty" pasture; regeneration with pasture; reforestation; and secondary vegetation. To study the spatial configuration of these data, the following landscape metrics were calculated: area/perimeter ratio, as an indicator of polygon shape; average area; density of polygons; and density of classes as indicators of landscape fragmentation.

2.2.3.3. Conservation Units

Information on all federal and state conservation units was retrieved from maps provided by the Brazilian Ministery of Environmental [46]. We recorded the percentage of the municipal area designated as a conservation unit.

2.2.4. Dimension 4: Social Characteristics

Socioeconomic development indices can be used as estimators of quality of life, and are relevant in the context of regional socioeconomic development analysis [49], although they should be applied with caution given their many limitations [50]. We used a Municipal Human Development Index (MHDI) and density of people living in poverty (data from the Atlas of Human Development in Brazil [51]) to assess whether the specialization in certain agricultural production systems was associated with social differences between groups of municipalities. We also retrieved data on the total number of inhabitants and the number of inhabitants in the rural zone for each municipality (data from a population estimates conducted by the IBGE [34]), and the areas of settlement projects within each municipality.

Although the MHDI is insufficient to fully capture the level of municipal human development, it does provide a synthetic view of some of the key development issues such as health, education and income [50]. A similar procedure was used for GDP and Agricultural Credit (see Sections 2.2.2.1. and 2.2.2.2.) which were used to create an index to represent the population from the deforested area within each municipality.

We also collected data of the boundaries of settlement projects for agrarian reform, aimed to account for the percentage on the municipality occupied by such projects. Polygons of the settlements were downloaded from the website of the National Institute of Colonization and Agrarian Reform (INCRA), a Brazilian federal agency responsible for agrarian reform and land consolidation [52].

Appendix A provides Table A1 with the assigned name of each metric (metric), a brief description, and the unit of measurement.

3. Metrics and Data Analysis

3.1. Identification of Agricultural Production Systems

Despite having major limitations, GDP is a key indicator of regional economic development [49]. To identify the predominant agricultural production system in each municipality, a metric was created to serve as an indicator of the economic efficiency of land use. This metric was derived from the hypothesis that Agricultural GDP 2010 divided by the deforested area 2010 in each municipality (metric **PIBAgroPRD_T2** in Appendix A) can be used to support the identification of agricultural production systems, because different productions systems should result in different economical improvements.

In our initial analysis, we treated PIBAgroPRD_T2 as a dependent variable and, using the 2010 TerraClass data, we performed an exploratory analysis to identify key trends (following [15]). In this exploratory analysis, we perceived that the percentage of clean pasture, dirty pasture and annual agriculture were an important factor for the separation of the municipalities in groups. Using an expert approach, we empirically arbitrate the classification of municipalities based on the proportional area of this land use/land cover classes. The analysis indicated the existence of three main groups: (1) The first group was associated with annual crop activity; (2) The second group with the predominance of "*clean pastures*"—characteristic of intensive livestock farming; and (3) The third group was associated with "*dirty pastures*"—characteristic of semi-intensive livestock farming. The identification of metrics and their value in classifying these three main groups was optimized empirically using specialized literature, empirical knowledge and exploratory analysis of the database, applied in the construction of the decision tree, which was designed from a set of rules defined by the expertise of the authors and other researchers. Its construction was guided by the "rule-based" approach [53].

In Rondônia, as throughout the Brazilian Amazon, there is a clear predominance of cattle pasture for beef production [54–56]. There are also areas characterized by a predominance of small farms, where dairy farming has significant local importance [57–59]. Unfortunately, it is not possible to separate pastures for beef production from those used for milk production using only TerraClass data. However, IBGE publishes annual figures for the size of cattle herds and the number of cows milked for each municipality. These two datasets can be combined to create a new metric that quantifies the relationship between the number of cows milked and the size of the local herd (metric **NVacReb_T2** in Appendix A). This metric allowed a new level of the decision tree to be added that was able to distinguish municipalities where dairy farming coexists with beef farming from those where dairy farming is rare or non-existent. Moreover, municipalities with dairy farming could be split between those under semi-intensive production systems and those with intensive production systems.

3.2. Characterization of Agricultural Production Systems

3.2.1. Concentration of Annual Crops and Coffee

Each production system uses different strategies that can be translated into greater or lesser specialization in production. These specializations lead to differences in the degree of concentration in the production of annual and/or perennial crops. Knowing the degree of this concentration thus strengthens the understanding of production systems.

We sought to identify the predominant annual crop by comparing the production value (in 2010; R$) of five main annual crops (rice, beans, cassava, corn and soybeans). These crops were chosen because they are the most commonly used annual crops in the state [35]. Using data on annual income (in 2010; R$) for each crop from IBGE's municipal agricultural research database [34], we calculated the percentage share of the production value for each of the five crops, identifying the culture with the largest financial contribution in each municipality.

Degree of diversification of agricultural activity was calculated based on the percentage share of each crop. Municipalities were classified as "*concentrated*" where agricultural income was predominantly derived from a single crop. In such concentrated municipalities, the financial importance of the main crop (C_1) accounted for over 67% of the total income generated by the five crops (e.g., the main crop generates more than twice the income of the remaining four crops). In 2010, the average percentage contribution of the first (C_1) and second (C_2) most important crop was 61% and 23%, respectively, which together accounted for 84% of total income. Municipalities were classified as "*conjugated*" when the main culture contributed less than 67% of total crop income and the sum of the percentages of the first and second culture was greater than 84% (*i.e.*, crop activity was concentrated in two main crops). The remaining municipalities were classified as "*diffused,*" reflecting that crop income was fairly evenly distributed between three or more crops. This set of rules is summarized in Table 1.

Table 1. Rules to classification degree of concentration crops.

Rules	Class of Concentration	Number of Principal Crops
$C_1 \geqslant 67\%$	"*concentrated*"	one crop
$C_1 < 67\%$ and $C_1 + C_2 \geqslant 84\%$	"*conjugated*"	two crops
$C_1 + C_2 < 84\%$	"*diffused*"	three or more crops

Coffee has an historical importance in agricultural production in Rondônia, ever since occupation of the territory in the 1970s [26]. The importance of coffee was estimated as its percentage of land cover in each municipality, calculated as: planted area of coffee [34] divided by the total area occupied by agriculture [33] in each municipality.

3.2.2. Verification of Metrics

We use analysis of variance (ANOVA) to identify differences between the profiles of agricultural production systems at the municipal level based on the metrics used to characterize the four dimensions of these systems (see Appendix A). The average values of these profiles were ordered in order to establish a possible hierarchy (significance level of 5% $-$ $\alpha = 0.05$; LSD test).

4. Results

4.1. Localization of Agricultural Production Systems

We successfully identified various metrics and values to be used as separation criteria in the decision tree. The main criterion branch was based on the land cover of annual crops and livestock rearing. Municipalities with annual crop land cover values above or equal to 10% were classified as belonging to the crop agriculture domain; below this figure they were classified as belonging to the livestock domain. These two domains were then further subdivided.

In the crop agriculture domain, municipalities characterized by less than 30% "clean" pasture were classified as strictly linked to crop agriculture (Dominant Crop Agriculture—**DCA**). Municipalities where mechanized crop agriculture coexists with substantial pasture areas (where the percentage of "clean" pasture is equal to or greater than 30%) were classified as coexistence zones between crop agriculture and the livestock domain (Coexistence Area—**CA**).

The livestock domain was subdivided based on presence of more than 60% of "clean" pasture. Municipalities meeting this criterion were characterized as intensive livestock farming. Municipalities with less than 60% of "clean" pasture were classified as semi-intensive livestock farming.

The presence of dairy farming was identified by the percentage of animals milked within the municipal flock. Municipalities with 10% or more milked animals were classified as having a significant presence of dairy farming: below this value they were classified as without a significant presence of dairy farming.

The above classification was applied to both the intensive and semi-intensive livestock systems to generate four groups; (i) intensive livestock farming without significant dairy farming (Intensive Beef—**IB**); (ii) intensive livestock farming with significant dairy farming (Intensive Beef Milk—**IBM**); (iii) semi-intensive livestock farming without significant dairy farming (Semi-Intensive Beef—**SIB**); and (iv) semi-intensive livestock farming with significant dairy farming (Semi-Intensive Beef Milk—**SIBM**). This decision tree is shown in Figure 1.

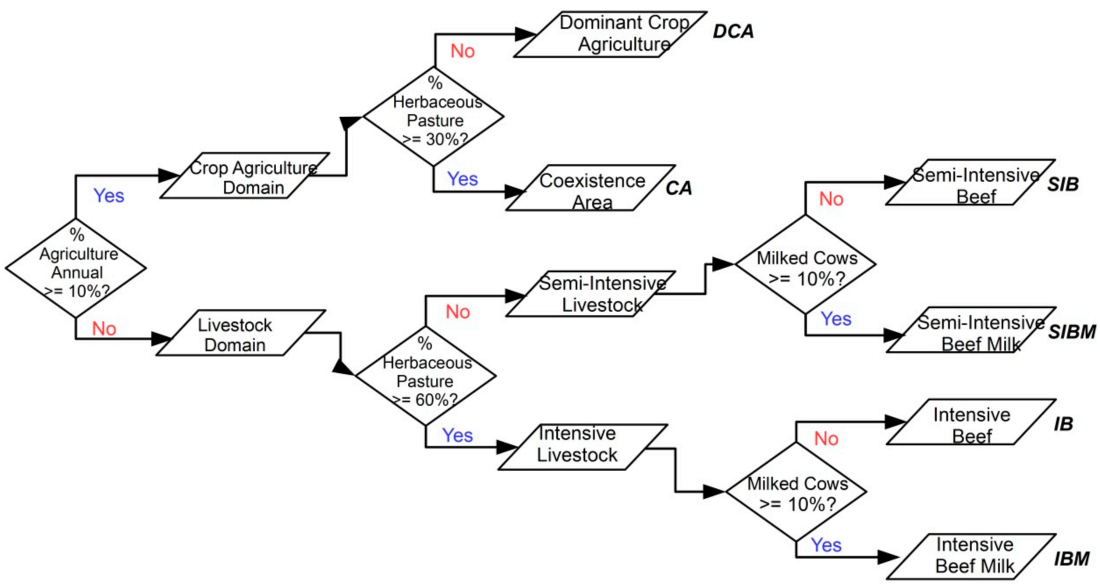

Figure 1. Decision tree to identify municipal agricultural systems in the State of Rondônia.

All the municipalities of Rondônia were classified into agricultural production systems using the decision tree (Figure 2) except from the capital city, Porto Velho, which has unique socioeconomic characteristics that led us to create the special class name *Capital*.

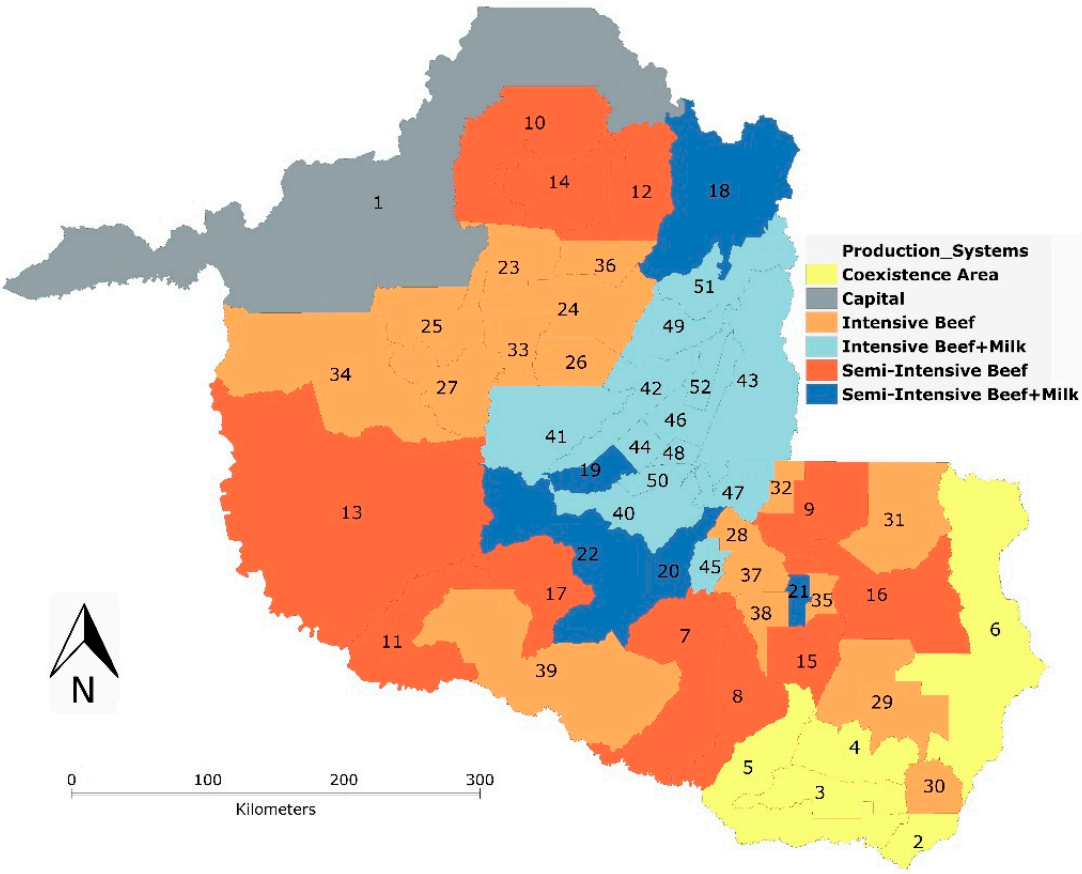

Figure 2. Distribution of agricultural production systems in Rondônia.

The numbers in Figures 2 and 3 represent the municipality name. The names of municipalities can be found in Table 2.

4.2. Characterization of Agricultural Production Systems

4.2.1. Concentration of Annual Crops

Following the methodology described in Section 3.2.1, the degree of concentration of the main five crops' production was identified (Table 2; Figure 3). In total, 18 municipalities were classified as "*concentrated,*" 7 as "*conjugated,*" and 26 as "*diffused.*" "Concentrated" municipalities were mainly located near state boundaries, while soybean (7 municipalities) and corn (6 municipalities) were mainly in the south of the state of respectively, corroborating both the literature [60] and land use data from the TerraClass project [33]. Cassava predominated in all regions of the state, except for the south, and was the main crop in 32 municipalities. Table A2 in the appended material shows the proportional economic contribution of the five major crops for each municipality.

Table 2. Concentration of the five major crops.

Production System	Concentration	Principal Crop	Municipality
CA	*"concentrated"*	Soybean	Cabixi (2), Cerejeiras (3), Corumbiara (4), Pimenteiras do Oeste (5), Vilhena (6)
IB	*"conjugated"*	Cassava	Rio Crespo (36)
		Corn	Espigão D'Oeste (31)
	"concentrated"	Cassava	Alto Paraiso (23), Buritis (25), Cacaulândia (26), Nova Mamoré (34)
	"diffused"	Rice	Ariquemes (24), Primavera de Rondônia (35), São Francisco do Guaporé (39)
		Cassava	Campo Novo de Rondônia (27), Castanheiras (28), Ministro Andreazza (32), Montenegro (33), Rolim de Moura (37)
		Corn	Santa Luzia D'Oeste (38)
		Soybean	Chupinguaia (29), Colorado do Oeste (30)
IBM	*"conjugated"*	Rice	Presidente Medici (47)
		Corn	Vale do Paraiso (52)
	"concentrated"	Cassava	Ji-Paraná (43), Ouro Preto do Oeste (46)
	"diffused"	Cassava	Alvorada D'Oeste (40), Gov.Jorge Teixeira (41), Jaru (42), Nova União (44), Novo Horizonte do Oeste (45), Teixeirópolis (48), Theobroma (49), Vale do Anari (51)
		Corn	Urupa (50)
SIB	*"conjugated"*	Cassava	Cacoal (9), Costa Marques (11)
	"concentrated"	Cassava	Candeias do Jamari (10), Cujubim (12), Guajara-Mirim (13), Itapuã do Oeste (14), Pimenta Bueno (16), Seringueiras (17)
	"diffused"	Cassava	Parecis (15)
		Corn	Alta Floresta do Oeste (7), Alto Alegre do Parecis (8)
SIBM	*"conjugated"*	Rice	São Miguel do Guaporé (22)
	"concentrated"	Cassava	Machadinho D'Oeste (18)
	"diffused"	Rice	São Felipe D'Oeste (21)
		Cassava	Mirante da Serra (19), Nova Brasilândia D'Oeste (20)

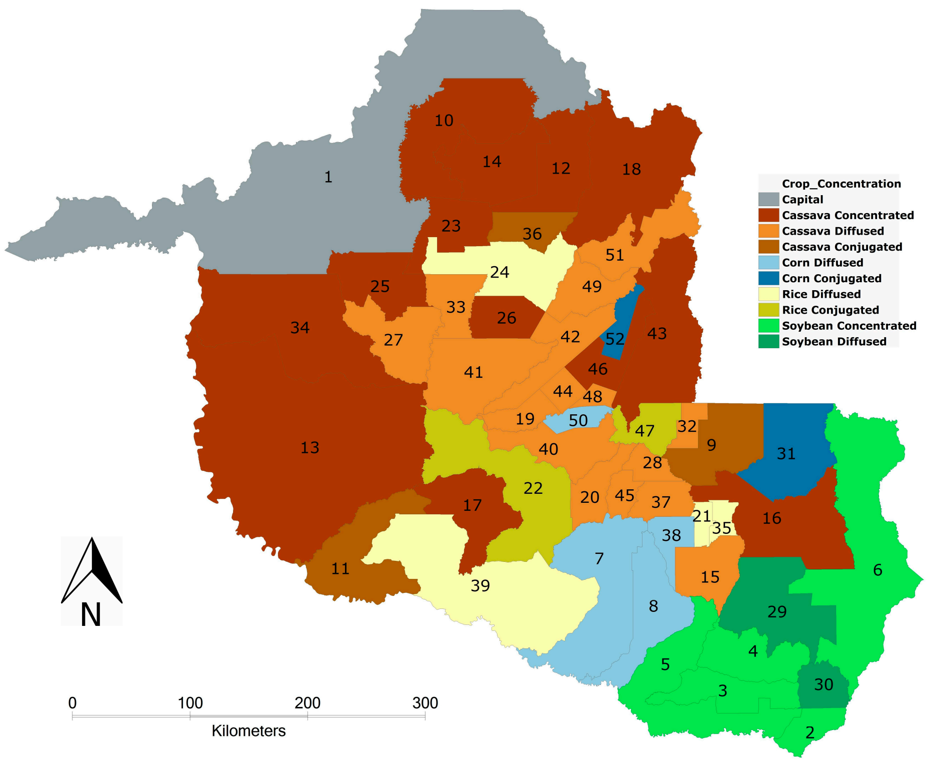

Figure 3. Localization and specialization of the five major crops in Rondônia (see text).

4.2.2. Quantitative Analysis of Production Systems

The methodology applied in this study allowed evaluating the performance of 49 calculated metrics, distributed in four dimensions. This result showed how each production system impacted the territory studied in the agricultural production, economic, territorial configuration and social characteristics. Table 3 shows these results in seven columns. The first shows the dimension and data source according to definitions adopted in Section 2.2. The second column identifies the metric name. The three to seven columns show the mean value of the attributes in production systems CA, IB, IBM, SIB and SIBM. The differences between production systems are shown in ascending order of average values by use of letters, where groups marked with the same letter are not significantly different from each other. Metrics where no production system differed from any other were not marked with letters (see Section 3.2.2).

Table 3. Mean values and statistical significance of metrics of different agricultural production systems.

		Agricultural Production System				
Dimension	**Metric**	**CA**	**IB**	**IBM**	**SIB**	**SIBM**
agricultural production (Section 2.2.1)	AMProp	2.65 (a)	1.24 (b)	0.69 (b)	1.45 (ab)	0.59 (b)
	NbovPast_T2	1.74 (ab)	2.05 (ab)	2.21 (a)	1.62 (b)	1.91 (ab)
	NvacReb_T2	5.49 (c)	5.93 (c)	19.67 (a)	4.87 (c)	15.18 (b)
	AMCafe_T2	50 (c)	2487 (bc)	3043 (abc)	3346 (ab)	7376 (a)
	DACafe_T2	0.04	0.11	2.21	2.66	2.27
economics (Section 2.2.2) *PIB (Sections 2.2.2.1.)*	PIB_T2	414,322.20	343,418.94	329,017.15	267,644.00	196,971.80
	PIBAgro_T2	98,103.80	87,592.06	72,330.62	80,524.00	75,123.80
	EvPIB_T1T2	292,951.80	246,097.56	222,601.00	211,807.58	145,211.20
	EvPIBAgro_T1T2	72,661.80	67,386.13	49,017.15	68,555.92	59,915.20
	PIBPRD_T2	286.55	184.94	195.06	160.52	201.73
	EvPIBPRD_T1T2	181.39	121.63	125.18	111.32	142.16
	PIBAgroPRD_T2	73.90	53.54	56.13	47.08	81.36
	EvPIBAgroPRD_T1T2	49.86	37.67	36.25	36.33	64.37
	PIBHab_T2	22.21 (a)	15.04 (ab)	12.26 (b)	13.95 (ab)	14.68 (ab)
	EvPIBHab_T1T2	16.71	10.95	8.61	10.26	11.27
	PIBAgroPopR_T2	34.54 (a)	12.66 (b)	8.44 (b)	13.64 (b)	9.56 (b)
	EvPIBAgroPopR_T1T2	26.51 (a)	10.09 (b)	6.45 (b)	11.56 (b)	8.09 (b)
economics (Section 2.2.2) *agricultural credit (Section 2.2.2.2.)*	NcrAg_T2	397.80	453.65	474.00	458.00	667.20
	NTCrAg_T1T2	4522.00	4582.00	6675.92	5673.55	8361.40
	RsMCrAg_T2	56.13 (a)	30.79 (ab)	29.45 (ab)	31.23 (ab)	12.56 (b)
	RsCrAgPRD_T2	15.35 (a)	7.38 (b)	10.23 (ab)	6.19 (b)	8.36 (a)
	RsMCrAgPRD_T1T2	8.95 (ab)	4.11 (ab)	4.58 (ab)	3.10 (b)	10.05 (a)
economics (Section 2.2.2) *logístics (Section 2.2.2.3.)*	DEst	7.95	6.97	6.76	15.36	8.59
	DHdr	0.058	0.047	0.061	0.062	0.066
territorial configuration (Section 2.2.3) *PRODES (Section 2.2.3.1.)*	AMPRD_T1T2 (km^2)	0.220 (a)	0.183 (b)	0.140 (c)	0.179 (b)	0.150 (c)
	APPRD_T1T2	62.02 (a)	60.36 (b)	52.81 (e)	59.41 (c)	55.94 (d)
	DDesf_T2 (%)	41.5 (b)	66.7 (a)	71.4 (a)	32.4 (b)	54.4 (ab)
	DDesf_T1T2 (%)	4.9	10.4	6.3	11.6	8.3
	TxMDesf_T1aT2 (%)	1.4 (b)	3.0 (a)	3.4 (a)	2.0 (ab)	2.3 (ab)
territorial configuration (Section 2.2.3) *TerraClass (Section 2.2.3.2.)*	AMPTC_T2 (km^2)	0.712	0.651	0.413	0.418	0.360
	APTC_T2	44.67 (a)	42.53 (c)	38.26 (e)	43.42 (b)	40.94 (d)
	DPTC_T2	1.94 (b)	3.17 (ab)	3.40 (a)	2.07 (ab)	3.18 (ab)
	DATCAA_T2	24.12 (a)	1.19 (b)	0.07 (b)	0.72 (b)	0.52 (b)
	DATCMO_T2	0.22 (b)	1.43 (b)	2.33 (ab)	1.58 (b)	6.23 (a)
	DATCPL_T2	45.07 (c)	68.79 (a)	73.52 (a)	52.90 (bc)	56.10 (b)
	DATCPS_T2	6.07 (b)	7.16 (b)	5.55 (b)	13.32 (a)	11.42(ab)
	DATCRP_T2	8.47 (a)	3.01 (b)	2.25 (b)	9.01 (a)	7.30 (a)
	DATCVS_T2	13.90	16.37	15.79	19.44	17.72
territorial configuration (Section 2.2.3) *conservation units (Section 2.2.3.3.)*	DAUPA (%)	29.1 (ab)	12.2 (b)	16.5 (b)	43.9 (a)	27.9 (ab)
social characteristics (Section 2.2.4)	IDHM_T2	0.67	0.65	0.64	0.63	0.64
	IDHM_T1aT2	0.16	0.17	0.18	0.16	0.18
	DPobre_T2	16.76	19.87	23.33	23.13	26.52
	EvDPobre_T1T2	−17.85	−15.89	−15.83	−16.45	−13.32
	DPAss	0.20	0.47	0.52	0.20	0.28
	PopR_T2	3486.00 (b)	7387.81 (ab)	8449.85 (ab)	6695.25 (ab)	9964.40 (a)
	EvPopR_T1T2	−657.80	−1141.31	−2959.54	408.42	−684.60
	PopRPRD_T2	2.62 (c)	4.81 (b)	6.97 (a)	4.24 (b)	8.08 (a)
	EvPopRPRD_T1T2	−0.99 (a)	−2.05 (ab)	−3.36 (bc)	−1.83 (a)	−3.59 (c)
	EvPopRPRD_T1T2 (%)	−24.31	−27.37	−32.48	−26.07	−29.06

5. Discussion

In this section, we discuss the differences between production systems in the context of the four analyzed dimensions.

5.1. Agricultural Production

For areas of coexistence between livestock production and intensive agriculture (**CA**), the predominant crop was soybean (Figure 4). In contrast, in all other production system-based livestock farming (**SIBM, IB, SIB**, **IBM**), cassava was the most important annual crop (Figure 4), thus reflecting its importance as a subsistence crop and its role in providing a supplementary income [57,61].

As with cassava, coffee cultivation predominated in cattle-based production systems (Figure 4), and only 0.04% of the area of municipalities was dominated by coexistence agriculture (**CA**). The area occupied by coffee was slightly higher in production systems that involve a substantial element of milk production (**IBM** and **SIBM**), perhaps indicating a greater compatibility in the production of these basic agricultural products.

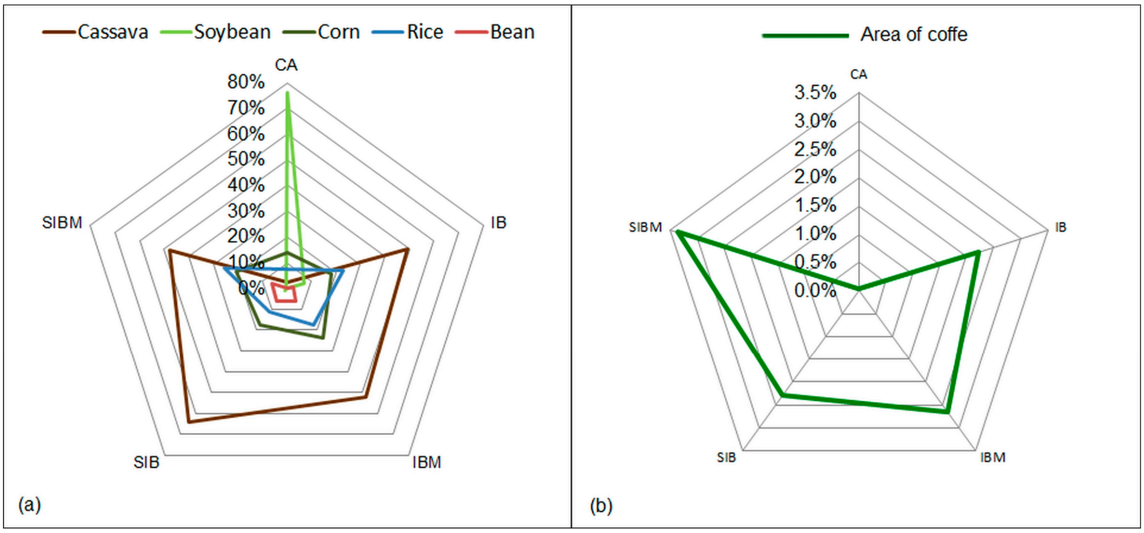

Figure 4. (**a**) Mean percentage of income generated from each major crop within each production system; (**b**) Mean percentage of area occupied by coffee in each production system.

The average size of the properties (**AMProp**) was higher for the **CA** Production System. This is in line with expectations, as grain crops require investment in larger tracts to increase profitability [62]. The **SIB** system had the second highest average area of property, probably because traditional livestock farming is characterized by low stocking densities which require extensive areas [63]. Moreover, smallholders use milk production to supplement their income [59]. The number of animals per grazing unit (**NbovPast_T2**) and the percentage of cows milked (**NvacReb_T2**) are also consistent with values reported in the literature, showing that municipalities with a predominance of "*clean pastures*" and dairy farming contribute to the increase in stocking. Indeed, stocking rates are higher than the national average and compatible with evolved technological systems [64,65].

5.2. Economics

GDP measures the economic value of agricultural, industrial and service activities [66]. Although the literature indicates that there is a relationship between GDP derived from agricultural activities and local development [19,67,68], we found no significant differences in average values of economic metrics for municipalities with different production systems, except for Agricultural GDP per capita for rural areas (**PIBAgroPopR_T2**) and changes in this metric between 2000 and

2010 (**EvPIBAgroPopR_T1T2**). In both metrics, the **CA** production system presented significantly higher values. This result supports the analysis of Le Tourneau [69], who demonstrated that highly mechanized production systems tend to have low population density, leading to higher values of GDP per capita.

Large variation in the absolute values of economic metrics linked to the GDP, may be associated with large variation in municipal land area and the size of the municipal population. Another problem is the estimate limitations of agricultural GDP, which may cause underestimates among sectors such as the subsistence economy in rural areas and the informal sector [49]. Regardless of consequences, this high variability contributed to the lack of statistical correlations related to metrics of GDP.

Average value per transaction of agricultural credit (**RsMCrAg_T2**) was highest in the **CA** production system, probably due to the high proportion of cultivated areas and the increased use of technology (e.g., seed and agricultural inputs with high cost production). The SIBM production system had the lowest value of **RsMCrAg_T2**, indicating that producers of this system when accessing the official agricultural credit, get smaller amounts of resources.

The amount of agricultural credit applied per km^2 deforested (**RsCrAgPRD_T2**) was also higher in the CA production system. For livestock systems, there was a difference between systems with and without a significant presence of dairy farming, with higher credit for those with dairy farming, and slightly higher values for intensive systems compared to semi-intensive systems.

Regarding the logistics segment, where we try to infer the degree of accessibility in the predominant production systems, no significant difference has been reported. Part of this result can be attributed to the heterogeneity of the surface extension of the municipalities. Perhaps a new form of consideration in the classification of the "order" of the access segment (rivers and roads), as well as the separate assessment of conservation areas can offer better results.

5.3. Territorial Configuration

Previous studies using deforestation data have demonstrated increased intensification of land use near established agricultural frontiers [70–72], as indicated by increases in local infrastructure and the price of land, or the lack of new areas to deforest. We found higher values for the percentage of deforested area in 2010 (**DDesf_T2**) for the **IB** and **IBM** production systems. These systems have the highest percentage of *clean pasture*, corroborating that a more intensive use of pasture is mainly associated with the lack of new areas for expansion [72]. While production systems **SIBM**, **SIB** and **CA** have the lowest deforestation values, the **SIB** system has higher levels of "*dirty pasture*", *i.e.*, "*regenerating pasture*" that are indicative of instability to the agricultural frontier. Unlike in **IB** or **IBM** land use systems, municipalities with the **SIB** system also tend to have significant portions of their territory within protected areas (as indicated by the **DAPUC** metric) that are not subject to legal deforestation. The low value of **DDesf_T2** in municipalities with the **CA** system, where annual crops are of great importance, may be a consequence of the conversion of low quality pastures for grain production systems. However, more data on temporal patterns of land use and land cover are needed to confirm this hypothesis.

In the Amazonian context, variations of the average rate of deforestation between 2000 and 2010 (**TxMDesf_T1aT2**) are small, and are concentrated in the beginning of the period. Rates were below 1% for all systems between 2009 and 2010, indicating a likely stabilization of deforestation in Rondônia State, since the current control and supervision policies are maintained. There was a higher average rate of deforestation for production systems linked to livestock compared to those linked to crop agriculture. This result supports the argument that intensification of land use has mainly occurred in well-established frontier areas. The change in deforested percentages between 2000 and 2010 (**Ddesf_T1aT2**) did not differ between production systems, although systems more closely associated with beef cattle had slightly higher values.

There was a lower proportion of protected areas (**DAPUC**) in municipalities with the **IB** and **IBM** production systems, thereby strengthening the association between these systems and the proportion of deforested areas (see above).

The average area in relation to the area/perimeter of "PRODES" polygons (comprising the annual polygons including deforestation before 2000) did not differ within the five production systems. This can be explained by the large aggregation of PRODES data before 2000. Deforestation data were aggregated into a single class containing all (deforested) polygons detected between 1988 and 1997. This aggregation added many polygons and misrepresented the results of the landscape analysis.

When only the polygons of the period from 2000 to 2010 were analyzed, the average area of deforested polygons (**AMPRD_T1aT2**) was lower in production systems with significant milk production. This result is in accordance with the claim that milk production occurs mainly in small properties that produce small clearings. In contrast, municipalities with the **CA** production system contain larger polygons, and systems linked to meat production show intermediate values. The value of the ratio area/perimeter of deforested polygons between 2000 and 2010 (**APPRD_T1T2**) was different in all production systems, following the same trend as for average size of polygons: average value was highest for municipalities with the CA system, followed by systems linked to the production of meat and, finally, systems related to the production of milk.

The average size of TerraClass 2010 polygons (**AMPTC_T2**) showed no statistical differences between production systems. The mean area/perimeter of TerraClass polygons 2000 to 2010 (**APTC_T1T2**) showed statistical differences between all systems, with higher values for the **CA** system, intermediate values for beef-associated systems, and the lowest values for milk-associated systems. These trends follow those for the PRODES data and are consistent with expectations: the polygons in municipalities with the CA system are more regular, presumably due to the high level of mechanization in this production system. Municipalities with milk-associated production systems had lower values, indicating more irregularly shaped polygons associated with a greater reliance on manual labor.

5.4. Social Characteristics

The metrics associated with the human development index (HDI) and density of people living in poverty showed no statistically significant differences between municipalities with different production systems, neither for the 2010 data, n for the evolution of the HDI between 2000 and 2010. Although quality of life may be associated with agricultural income [67], production systems alone did not seem to strongly influence development metrics.

The rural populations in 2010 (**T2**) were lower in municipalities with the CA production system, indicating a low level of manpower in areas with a predominance of mechanized agriculture. Conversely, municipalities with milk-associated systems had higher rural populations because of their greater need for manual labor. All production systems showed a decrease in rural population (ranging from −24.31% to −32.48%) in relation to the deforested area between 2000 and 2010 (**PopRPRD_T1aT2**), thereby indicating a displacement of the rural population during this period even as deforestation and agricultural production increased. Other factors may have contributed to this displacement of the rural population, such as the installation of enormous hydroelectric plants of Jirau and Santo Antonio. Such mega-projects significantly impacted migration and work availability in the region [73,74]. These results are in agreement with results of other studies in the State of Rondônia [7,75].

6. Conclusions

Deforested areas in Rondônia have been converted into a variety of agricultural uses. Using a combination of land use and socioeconomic data, we were able to identify five main production systems associated with mechanized agriculture (**CA**), livestock farming in semi-intensive (**SIB** and **SIBM**) or intensive (**IB** and **IBM**) regimes, with or without the presence of dairy farming.

Production systems linked to mechanized agriculture and clean pastures were predominantly found in the consolidated region of the agricultural frontier, while pasture-based systems with "*dirty pasture*" tended to be located in regions of recent agricultural expansion. Moreover, production systems linked to milk production had a higher rural population. The methodology we adopted, using municipal administrative boundaries as a unit of analysis, was not sufficiently sensitive to detect significant differences in GDP generated by the different production systems. All production systems linked to livestock had stocking rates similar to or better than the national averages. Our landscape analysis indicated that the relationship area/perimeter of PRODES and TerraClass data varied significantly, with higher values in regions with predominantly mechanized agriculture and lower values for regions characterized by beef farming and, especially, milk production. This pattern was also reflected in a gradation in the shape of area polygons, with simpler, more regular forms associated with the **CA** system and more complex, irregular forms associated with the **IBM** and **SIBM** systems.

The results in the dimension territorial configuration were promising, even at the scale of sociopolitical units of municipalities. From these results, the possibility of a landscape analysis with a more detailed level, performed by using cell arrays, is inferred.

The results of this study can serve as a valuable baseline for future studies that utilize predictive models to assess the impact of expansion or contraction of certain production systems. By assessing the consequences of different plausible scenarios of agricultural development, such studies have the potential to provide a robust system for the evaluation of public policies.

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Abbreviations

The following abbreviations are used in this manuscript:

EMBRAPA	Brazilian Agricultural Research Corporation—*Empresa Brasileira de Pesquisa Agropecuária* (in Portuguese)
GDP	Gross Domestic Product—*Produto Interno Bruto*
IBGE	Brazilian Institute of Geography and Statistics—*Instituto Brasileiro de Geografia e Estatística*
INCRA	National Institute of Colonization and Agrarian Reform*Instituto Nacional de Colonização e Reforma Agrária*
INPE	Nacional Institute for Space research—*Instituto Nacional de Pesquisas Espaciais*
MHDI	Municipal Human Development Index—*Indice de Desenvolvimento Humano Municipal* (in portuguese)
PRODES	Project for the Monitoring of Brasilian Amazon Forest by satellite—*Projeto de Monitoramento da Floresta Amazônica Brasileira por Satelite*
SIPAM	*Amazon Protection System—Sistema de proteção da Amazônia*
TerraClass	Project for Monitoring the Land Use Land Cover in Brazilian Amazon—*Projeto de Monitoramento do Uso e Cobertura da terra na Amazônica Brasileira*

Appendix A

Metrics

Table A1 provides the names of the variables analyzed, organized by dimension, and gives a small description of each metric and its respective measurement unit.

Table A1. Metrics adopted and units of measurement.

Dimension	Metric	Description	Unit
agricultural production (Section 2.2.1)	AMProp	Mean area of properties within municipality (total area of properties/total number of properties)	km^2
	NbovPast_T2	Average capacity of TerraClass (Clean, dirty and regenerating) pastures = Total number of cattle in municipality 2010/Total number of TerraClass pastures in 2010	Cattle/ha
	NVacReb_T2	Proportion of milk cows within the total cattle population	%
	AMCafe_T2	Mean cultivation area of coffee in the municipality in 2010	ha
	DACafeT2	Percent of deforested area in each municipality cultivated by coffee in 2010	%
economics (Section 2.2.2) *PIB (Section 2.2.2.1.)*	PIB_T2	Municipal GDP in 2010	R$ × 1000
	PIBAgro_T2	Municipal GDP for agricultural sector in 2010	R$ × 1000
	EvPIB_T1T2	Evolution of GDP (2000 to 2010) = GDP 2010 – GDP 2000	R$ × 1000
	EvPIBAgro_T1T2	Evolution of agricultural GDP (2000 to 2010) = agricultural GDP 2010 – agricultural GDP 2000	R$ × 1000
	PIBPRD_T2	Relationship between GDP in 2010 and mean deforestation from PRODES in 2010	R$ × 1000/km^2 PRODES
	EvPIBPRD_T1T2	Evolution of PIBPRD between 2000 and 2010 = PIBPRD_T2 – PIBPRD_T1	R$ × 1000/km^2 PRODES
	PIBAgroPRD_T2	Relationship between agricultural GDP in 2010 de 2010 and mean deforestation from PRODES in 2010	R$ × 1000/km^2 PRODES
	EvPIBAgroPRD_T1T2	Evolution of PIBAgroPRD between 2000 and 2010. = PIBAgroPRD_T2 – PIBAgroPRD_T1	R$ × 1000/km^2 PRODES
	PIBHab_T2	Relationship between GDP 2010 and human population of municipality	R$ × 1000/hab.
	EvPIBHab_T1T2	Evolution of the relationship between GDP and human population of municipality 2000–2010	R$ × 1000/hab.
	PIBAgroPopR_T2	Relationship between GDP and human population of the rural zone of the municipality in 2010	R$ × 1000/hab.
	EvPIBAgroPopR_T1T2	Evolution of the relationship between GDP and human population of the rural zone of the municipality 2000–2010	R$ × 1000/hab.
economics (Section 2.2.2) *agricultural credit (Section 2.2.2.2.)*	NcrAg_2010	Mean number of agricultural credit operations in municipality in 2010	Unit
	NTCrAg_T1T2	Mean number of agricultural credit operations in municipality 2000–2010	Unit
	RsMCrAg_T2	Mean value of agricultural credit operations in municipality in 2010	R$ × 1000
	RsCrAgPRD_T2	Relationship between total agricultural credit in 2010 and mean deforestation up to 2010 from PRODES	R$ × 1000/km^2 Deforest.
	RsmCrAgPRD_T1T2	Relationship between total agricultural credit in 2010 and mean deforestation between 2000 and 2010 from PRODES	R$ × 1000/km^2 Deforet.
economics (Section 2.2.2) *Logística (Section 2.2.2.3.)*	DEst	Relationship between the total perimeter of roads and the total municipal area	km/km^2
	DHdr	Total perimeter of polygons and vectors for hydrography of municipality/total area of municipality	km/km^2
territorial configuration (Section 2.2.3) *PRODES (Section 2.2.3.1.)*	AMPRD_T1T2	Mean area of PRODES polygons 2000–2010	km^2
	APPRD_T1T2	Area/Perimeter of PRODES polygons 2000–2010	-
	DDesf_T2	% deforestation in municipality from PRODES for 2010	%
	DDesf_T1T2	Evolution of % deforestation in municipality from PRODES between 2000 and 2010 = DdesfT2 – DdesfT1	%
	TxMDesf_T1T2	Mean rate of annual deforestation 2001–2010 from PRODES.	%

Table A1. *Cont.*

Dimension	Metric	Description	Unit
territorial configuration (Section 2.2.3) *TerraClass (Section 2.2.3.2.)*	AMPTC_T2	Mean area of TerraClass 2010 polygons	km^2
	APTC_T2	Area/Perimeter of TerraClass 2010 polygons	-
	DPTC_T2	Density of TerraClass 2010 polygons	poligons/km^2
	DATCAA_T2	Density of annual crop class from TerraClass 2010	%
	DATCMO_T2	Density of mosaic occupation class from TerraClass 2010	%
	DATCPL_T2	Density of clean pasture class from TerraClass 2010	%
	DATCPS_T2	Density of dirty pasture class from TerraClass 2010	%
	DATCRP_T2	Density of regerating pasture class from TerraClass 2010	%
	DATCVS_T2	Density of secondary vegetation class from TerraClass 2010	%
territorial configuration (Section 2.2.3) *Unidades Conservação Ambiental (Section 2.2.3.3.)*	DAUPA	% area of conservation units within municipality	%
Social characteristics (Section 2.2.4)	IDHM_T2	Human development index (HDI) for 2010, composed of three dimensions of human development: longevity, education and income	Index (0 to 1)
	IDHM_T1aT2	Evolution of municipal HDI between 2000–2010	Index (0 to 1)
	DPobre_T2	% of adults with an income equal to or below R$14,000 per month in August 2010	% of municipal population
	EvDPobre_T1T2	Change in % of people living under poverty between 2000 and 2010	% of municipal population
	DPAss	% municipal area occupied by settlement projects	%
	PopR_T2	Population of the rural zone (demographic census 2010)	Unit
	EvPopR_T1T2	Change in population in rural zone 2000–2010	Unit
	PopRPRD_T2	Relationship between population of the rural zone and mean deforestation to 2010 from PRODES	inhabitants /km^2 Deforest.
	EvPopRPRD_T1T2	Change in relationship between population of the rural zone and deforested from PRODES data, areas between 2000 and 2010	inhabitants /km^2 Deforest.
	EvPopRPRD_T1T2 (%)	% change in relationship between population of the rural zone in 2010 and mean deforestation from PRODES until 2010	%

Table A2 provides the proportional economic contribution of the five major crops' unit, and the classification of crop concentration in each municipality.

Table A2. Proportional economic contribution of the five major crops.

		% Economic Contribution						
Municipality	**Production System**	**Rice**	**Beans**	**Cassava**	**Corn**	**Soybean**	**Concentration**	**Principal Crop**
Cabixi	**CA**	4%	0%	4%	13%	79%	*"concentrated"*	Soybean
Cerejeiras		11%	0%	2%	20%	67%	*"concentrated"*	Soybean
Corumbiara		12%	0%	3%	11%	74%	*"concentrated"*	Soybean
Pimenteiras do Oeste		7%	0%	1%	2%	90%	*"concentrated"*	Soybean
Vilhena		3%	0%	1%	25%	71%	*"concentrated"*	Soybean
Rio Crespo	**IB**	40%	1%	50%	8%	1%	*"conjugated"*	Cassava
Espigão D'Oeste		14%	1%	42%	43%	0%	*"conjugated"*	Corn
Alto Paraiso		11%	1%	85%	3%	0%	*"concentrated"*	Cassava
Buritis		6%	2%	76%	15%	0%	*"concentrated"*	Cassava
Cacaulândia		1%	0%	96%	4%	0%	*"concentrated"*	Cassava
Nova Mamoré		1%	1%	91%	7%	0%	*"concentrated"*	Cassava
Ariquemes		44%	2%	26%	18%	10%	*"diffused"*	Rice
Primavera de Rondônia		48%	1%	33%	18%	0%	*"diffused"*	Rice
São Francisco do Guaporé		41%	0%	31%	28%	0%	*"diffused"*	Rice
Campo Novo deRondônia		26%	3%	42%	29%	0%	*"diffused"*	Cassava
Castanheiras		28%	0%	56%	16%	0%	*"diffused"*	Cassava
Ministro Andreazza		12%	5%	62%	21%	0%	*"diffused"*	Cassava
Montenegro		30%	4%	43%	24%	0%	*"diffused"*	Cassava
Rolim de Moura		19%	7%	53%	21%	0%	*"diffused"*	Cassava
Santa Luzia D'Oeste		21%	15%	29%	35%	0%	*"diffused"*	Corn
Chupinguaia		18%	0%	3%	14%	65%	*"diffused"*	Soybean
Colorado do Oeste		29%	1%	19%	8%	44%	*"diffused"*	Soybean

Table A2. *Cont.*

Municipality	Production System	% Economic Contribution					Concentration	Principal Crop
		Rice	Beans	Cassava	Corn	Soybean		
Presidente Medici	IBM	46%	1%	42%	11%	0%	*"conjugated"*	Rice
Vale do Paraiso		6%	3%	24%	67%	0%	*"conjugated"*	Corn
Ji-Paraná		2%	1%	83%	14%	0%	*"concentrated"*	Cassava
Ouro Preto do Oeste		2%	1%	92%	6%	0%	*"concentrated"*	Cassava
Alvorada D'Oeste		38%	3%	39%	19%	0%	*"diffused"*	Cassava
Gov.Jorge Teixeira		8%	24%	45%	23%	0%	*"diffused"*	Cassava
Jaru		11%	12%	61%	16%	0%	*"diffused"*	Cassava
Nova União		12%	13%	56%	18%	0%	*"diffused"*	Cassava
Novo Horizonte do Oeste		34%	6%	38%	22%	0%	*"diffused"*	Cassava
Teixeirópolis		14%	3%	49%	35%	0%	*"diffused"*	Cassava
Theobroma		20%	3%	55%	22%	0%	*"diffused"*	Cassava
Vale do Anari		24%	2%	58%	17%	0%	*"diffused"*	Cassava
Urupa		9%	10%	39%	42%	0%	*"diffused"*	Corn
Cacoal	SIB	13%	2%	58%	27%	0%	*"conjugated"*	Cassava
Costa Marques		24%	2%	66%	8%	0%	*"conjugated"*	Cassava
Candeias do Jamari		4%	0%	95%	1%	0%	*"concentrated"*	Cassava
Cujubim		14%	5%	77%	5%	0%	*"concentrated"*	Cassava
Gujara-Mirim		1%	0%	93%	5%	0%	*"concentrated"*	Cassava
Itapuã do Oeste		12%	4%	72%	3%	9%	*"concentrated"*	Cassava
Pimenta Bueno		10%	0%	80%	9%	0%	*"concentrated"*	Cassava
Seringueiras		15%	1%	74%	9%	0%	*"concentrated"*	Cassava
Parecis		14%	3%	46%	37%	0%	*"diffused"*	Cassava
Alta Floresta do Oeste		7%	27%	20%	46%	0%	*"diffused"*	Corn
Alto Alegre do Parecis		10%	24%	26%	40%	0%	*"diffused"*	Corn
São Miguel do Guaporé	SIBM	44%	1%	43%	11%	0%	*"conjugated"*	Rice
Machadinho D'Oeste		10%	3%	76%	12%	0%	*"concentrated"*	Cassava
São Felipe D'Oeste		41%	13%	8%	38%	0%	*"diffused"*	Rice
Mirante da Serra		15%	8%	51%	26%	0%	*"diffused"*	Cassava
Nova Brasilândia D'Oeste		18%	5%	62%	16%	0%	*"diffused"*	Cassava

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