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Environment

Rural agroecosystems under the sustainability aspect: an analysis in the southern Amazonas state

Agroecossistemas rurais sob o aspecto da sustentabilidade: Uma análise no Sul do Amazonas

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ABSTRACT

Sustainable development seeks to improve people's lives and associates economic development and environmental preservation with proper management of natural resources. The objective of this study was to evaluate the sustainability of agroecosystems, based on some sustainability indicators, covering the economic, social and environmental dimensions of rural and rural riverside properties in the southern Amazon region, a predominantly family farming region. The research was based on the SIA - Sustainability Indicators in Agroecosystems, carried out in an interdisciplinary and participative way, and for this purpose, it was necessary to contextualize the bases of the theoretical currents of sustainable development, establishing the historical and current insertion of family agriculture, addressing the attributes of sustainability in the socioeconomic and environmental dimensions. The methodological proposal applied was multivariate statistical analysis, Principal Component Analysis, from the three production systems, in order to identify the similarities underlying all the multiple relationships existing between the indicators, for the construction of the Sustainability Index (SI). Through the use of graphs and tables it was possible to evaluate the production systems in an integrated way and it was verified that the systems are different even though they are inserted in the same region and present a regular sustainability index.

Keywords: Agroecosystem; Sustainable development; Family farming; Statistical tools; Amazon

RESUMO

O desenvolvimento sustentável, busca melhorar a vida das pessoas e associa desenvolvimento econômico e preservação ambiental, pelo manejo adequado dos recursos naturais. Este trabalho teve como objetivo avaliar a sustentabilidade dos agroecossistemas, a partir de alguns indicadores de sustentabilidade, abrangendo as dimensões econômica, social e ambiental, em propriedades rurais e rurais ribeirinhas, na região sul do Amazonas, predominante de agricultura familiar. A pesquisa foi fundamentada na proposta ISA – Indicadores de Sustentabilidade em Agroecossistema, executada de forma interdisciplinar e participativa; para isso, fez-se necessário contextualizar as bases das correntes teóricas do desenvolvimento sustentável, estabelecendo a inserção histórica e atual da agricultura familiar, abordando os atributos da sustentabilidade nas dimensões socioeconômica e ambiental. A proposta metodológica aplicada foi: Análise estatística multivariada, Análise de Componente Principal, a partir dos três sistemas produtivos, a fim de identificar as semelhanças subjacentes à totalidade das múltiplas relações existentes entre os indicadores, para a construção do Índice de Sustentabilidade (IS). Por meio do uso de gráficos e tabelas foi possível avaliar os sistemas produtivos de forma integrada e constatou-se que os sistemas são diferentes embora estejam inseridos numa mesma região e apresentarem índice de sustentabilidade regular.

Palavras-chave: Agroecossistema; Desenvolvimento sustentável; Agricultura familiar; Análise estatística; Amazonas

1 INTRODUCTON

The concept of sustainable development seeks a new pattern of economic development, capable of simultaneously satisfying the environmental and social dimensions, in the face of socioeconomic dynamics, since the model of economic development based on capitalism has proved incapable of solving social problems such as the agrarian question, environmental depredation, precarious living conditions, among others. Existing post-war capitalism-based development models, such as the European Keynesian pact and the peripheral-developmental model, have caused a growing and continuing increase in social inequalities, raising the number of unemployed throughout the world, despite public and private initiatives aimed at sustainable development (Silva, 2010).

According to Ribeiro (2012), the proposal for sustainable development proposed in the Bruntland report recognizes the need to reduce inequalities between nations and power relations between northern and southern countries through guidelines for population control, conservation of resources development of sustainable technologies, alteration of the energy matrix, among others. It should be noted that neoliberalism and the globalization of economies bring a new world order, imposing an increasingly fast pace in the process of appropriation of resources, causing significant changes in natural and human environments, with greater environmental degradation.

According to Seramim and Lago (2016), the sustainability of rural properties is related to the adequate management of natural resources, since the conventional management of these resources has increased the environmental degradation. For the authors, sustainability is directly associated with the agro-ecological concepts developed in recent years, since agro-ecological management is more efficient in relation to the maintenance of biodiversity and ecosystem services, presenting itself as a preponderant factor for “sustainability” in the sense to enable farmers to remain in the countryside, contributing to rural development not only of property, but also of the local community and the region.

In this context, agroecology is presented as a path to sustainable agriculture, since this is based on knowledge and techniques developed from farmers and experimental processes, enabling a sustainable production in agroecosystem, originating from the balance between different species of nutrients, soil biological activity, diversification of species of plants, sunlight, humidity, among others, necessary for plants to become resilient, tolerating stress and adversities (Altieri & Toledo, 2011).

It is important to emphasize that the restriction of the availability of natural resources, considered a factor limiting the expansion of the economy, can be achieved by means of an adequate management of natural resources, with a view to preserving and expanding the biodiversity of agroecosystems, establishing the interaction between plant, soil and animal cultures, enabling the regeneration of soil fertility, maintaining crop productivity and protection, diversifying the agricultural landscape, being a preponderant factor for sustainability.

For this reason, a growing concern of society on issues related to the environment and the maintenance of biodiversity on the planet, as well as the development of public policies aimed at improving the living conditions of the rural people, Accessibility roads, basic essential services health, education, energy and treated water. In this process of transformation and change, deconstruction and construction of knowledge, there is family farming, recognized as being of extreme importance by the number of existing establishments and their economic importance, due to put on the table of Brazilian healthy food needed.

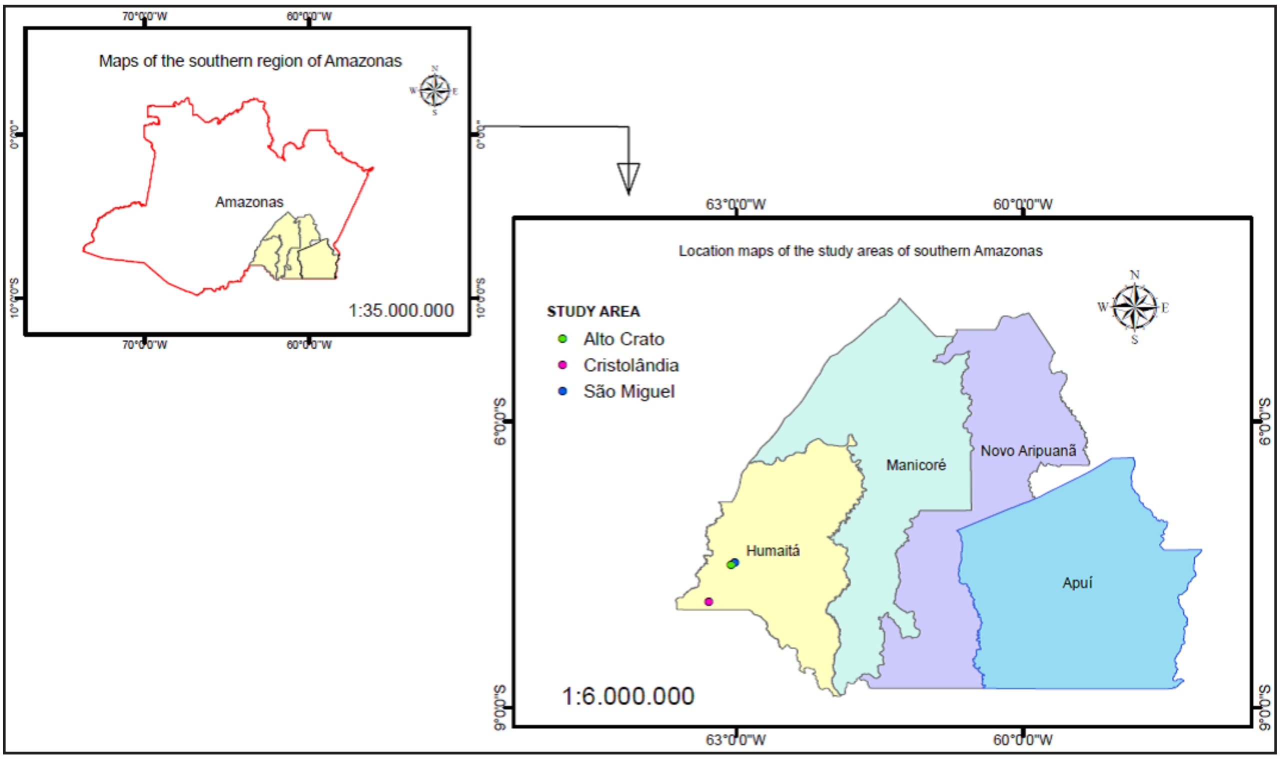
In this scenario, it is necessary to evaluate the sustainability of rural properties and the productive method employed, in order to adapt public policies and productive practices, with better use of renewable natural resources, to better understand the environment and to interact with it, sustainability of the planet.

2 MATERIALS AND METHODS

2.1 Characterization of the study area

The study area is located in the municipality of Humaitá, belonging to the mesoregion of the Amazonian South and microregion of Madeira and has an extension of about 33,129.131 km² (Figure 1). Cartesian coordinates: it is situated at 7º 30` 22`` south latitude and at 63º 01` 15`` longitude west of Greenwich, altitude of 58 meters above sea level. It borders with the municipalities of Manicoré to the north and east, Porto Velho and Machadinho D'Oeste, in the state of Rondônia, to the south and Tapauá and Canutama to the west. The municipality of Humaitá is bathed by the Madeira River, one of the main tributaries of the Amazon River, its population is estimated at 52,354 inhabitants (IBGE, 2016). The fiscal module established for the region is 100 hectares, and serves as a parameter for the classification of the property as small, medium or large property, and properties with up to four fiscal modules are considered small properties (Embrapa, 1997).

Figure 1 – Map of Amazonas, highlighting the Southern Region of the State of Amazonas (municipality of Humaitá), where the study areas are located



Source: Authors (2018)

The studied communities comprise three distinct systems, in rural areas and rural riverside areas of the municipality of Humaitá, predominant of family agriculture, properties with a total area of up to 100 hectares, namely: Cristolândia community (Gleba Antonieta Athaíde), Alto community and São Miguel community.

The Cristolândia System is located along the highway BR 319, Gleba Antonieta Athaíde, in a region characterized in upland soil, settlement of the National Institute of Colonization and Agrarian Reform (INCRA), distributed over thirty years for the inhabitants from other regions of the country, with emphasis on the state of Bahia.

The Alto Crato System is located along the vicinal of Alto Crato, in a region characterized by hybrid soil (upland and lowland), the inhabitants of the region are mostly from the interior of the Amazon (riverine), which for more than thirty years live in the region and live on agriculture, fish farming and extractivism.

The São Miguel System is located on the banks of the Madeira River, where the Madeira River is its main means of access. Similar to the other systems, terrestrial transport can also be used as a means of locomotion, through the Vicinal do São Miguel. The region is characterized by floodplain soil and suffers from floods that vary according to the level of the waters by the flood and ebb phenomena, and its inhabitants are mostly from the interior of the Amazon (riverine), which for more than fifty years live in the region and live on agriculture, fishing and extractivism.

In general, the soil variation of the region reflects the characteristics of the source material being classified as Yellow Latosols or Yellow Red Latosols that occupy an area of 52.5%, presents a strongly acidic reaction, with PH between 3.5 and 5.5 Red-Yellow Argisol, presents low fertility and represent about 23.5% of the total soils in the region, and also presents a lower proportion of Plintosols with 6.5% occurrence, soils with high saturation for Aluminum and low fertility, the Gleissolos that cover an area of 3.5%, soils with high saturation by Al and low fertility, present in the flooded areas, and the Spodosols with a representative of 2.5%, present in the flooded areas and Neosols, with 6.5% (Brazil, 1978).

Finally, with regard to climatic characterization, the climate of the region, according to the classification of Köppen belongs to group Tropical Rainy, with type Am precipitation (monsoon rainfall), with maximum from October to June, which varies between 2200 and 2800 mm per year and a dry period from July to September. The mean annual temperatures vary between 25 and 27 °C and the relative air humidity between 85 and 90% (Brazil, 1978).

2.2 Field Methodology

Data collection was performed in the months of October, November and December 2017. The work was developed in an interdisciplinary way, with the participation of the farmers of the communities and the questionnaire applied to the owners of agroecosystems, sought information about the social, ecological and economic dimensions of the production unit, in order to generate indicators that represent productivity attributes, stability, resilience and equity, and each of these dimensions.

In addition, in order to adapt the research to the reality to be studied, a pre-test of the questionnaire was applied to three farmers of the studied communities, not participants of the research, in order to adjust the questionnaire to the researched object and to guarantee the good quality of the instrument. After that, a field visit was carried out in the studied properties, with the purpose of applying the questionnaire with the owner, to make a verification of the producing units, plots and areas where there are permanent and temporary crops, fallow, non-agricultural areas, portions of water, native vegetation, legal reserve and Permanent Preservation Areas (APPs), and surface and underground water collection points, with estimated duration of three hours.

Therefore, the surveys of the selected communities were made, considering the information obtained from the National Institute of Colonization and Agrarian Reform (INCRA), the Amazon Development Institute (IDAM) and the Agro-Livestock Defense Agency and the Amazonas Agriculture and Forestry Agency (ADAF), related to rural and rural riversides properties, in order to select the population and define the sample within the universe researched, considering for the universe of the research properties that have a total area of 1 to 100 hectares, that develop agricultural and extractive activities, and thus define the quantity of properties to be surveyed and the number of questionnaires to be applied from a 95% confidence, through the following equation:

$$n = \frac{N \times n_0}{N + n_0}, \qquad (1)$$

with:

$$n_0 = \frac{z^2 \times \pi(1-\pi)}{E_0^2},$$

in which: N is the size of the population; z is the confidence interval (95%); **π** is the proportion in the sample (0.5) and E_0 is the tolerable sample error (0.05).

The sample population indicated is: Alto Crato community has 62 active properties, of which 14 have an area of over 100 hectares, at the time 31 field questionnaires were applied, from a studied universe of 48 rural properties; The community of Cristolândia (Gleba Antonieta Ataíde) has 51 (fifty one) active properties, of which 18 have an area of more than 100 hectares and 24 questionnaires have been applied in the field, in a studied universe of 33 rural properties; and the community of São Miguel has 35 active properties and 25 field questionnaires were applied in a studied universe of 35 rural properties.

The 80 (eighty) selected production units of the three communities where the research was applied correspond to an area of 2.347 hectares, and the main cultivated crops are: banana, cassava, flour, açaí, cupuaçu and leguminous vegetables. The predominant type of farm in the region is family farming, where family members are the majority of the workforce and properties are passed on to future generations, mainly in the community of Alto Crato and São Miguel.

It was decided to perform an exploratory sample, adopting a non-probabilistic model, with representativeness of the samples within each universe, obtained through a descriptive field research, requiring a quantitative and qualitative approach, with the purpose of discovering and observing phenomena, trying to describe, classify and interpret them, pointing out possible causes that constitute the problematic in question.

2.3 Data processing

With the field survey data (questionnaire) the next step of the research was the tabulation of the data, according to the categories, to organize them for content analysis, standardizing the criteria of values assigned to the variables in order to avoid possible discrepancies in the analysis between different properties. Data for characterization and evaluation of each farm were recorded and processed in a standard spreadsheet, created on the Excel platform.

The data compiled gave rise to a set of 21 sustainability indicators (table 1), which covers the socioeconomic and environmental aspects, calculated from the information collected in the field survey and evaluated within a range between 0 and 1 (Ferreira et al., 2012).

Table 1 – Description of the aspects of the 21 sustainability indicators used in the research activity developed in the communities of CR, AC and SM, in the South of Amazonas

Aspects	Indicators	Maximum score
Socioeconomic Aspects	1- Productivity	0 - 1
	2- Income diversification	0 - 1
	3 - Shareholders' equity	0 - 1
	4- Degree of indebtedness	0 – 1
	5- Basic Services / Food Security	0 – 1
	6- Education, Training	0 – 1
	7- Quality of Employment Generated	0 - 1
	8- Enterprise Management	0 – 1
	9- Information Management	0 – 1
	10- Waste Management	0 – 1
	11- Work Safety	0 – 1
	12- Remain in Agriculture	0 – 1
Aspects	**Indicators**	**Maximum score**
Environmental Aspects	13- Risk of Contamination	0 - 1
	14- Evaluation of Degraded Soils	0 - 1
	15- Conservation Practices	0 – 1
	16- Roads	0 – 1
	17- Native Vegetation	0 – 1
	18- Permanent Preservation Areas (APPs)	0 - 1
	19- Legal Reserve (RL)	0 – 1
	20- Diversification of the Agricultural Landscape	0 – 1
	21- Management of Production Systems	0 – 1

Source: Adapted from Ferreira et al. (2012)

For the determination of each indicator an index is generated and the resulting values are obtained from functions that assign value to the variables, using weighting factors for each parameter evaluated (Ferreira et al., 2012). The reference value is 0.7, defined as the base value and considered the sustainability threshold, which corresponds to good environmental, economic or social performance (Rodrigues,

& Campanhola, 2003; Ferreira et al., 2012). In this research, these ranges of notes were chosen based on the works developed by Ferreira et al. (2012) and on usual performance evaluation scales (Table 2).

Table 2 – Classification of the Environmental Sustainability Index

Category	Sustainability Index Interval
Sustainable:	SI ≥ 0.70
Sustainability Regular	SI 0.70 ≥ 0.50
Committed Sustainability	SI 0.50 ≥ 0.30
Unsustainable	SI < 0.30

Source: Adapted from Ferreira et al. (2012)

2.4 Statistical analysis

The multivariate statistical methodology, factor analysis, based on the analysis of principal components (FA/PCA), which linearly decomposes an unprecedented set of variables into a substantially smaller set of uncorrelated variables capable of characterizing a given phenomenon to identify the similarities underlying all of the multiple relationships between indicators for the construction of the Sustainability Index (SI). Principal components analysis was based on the assumption that one can determine statistically correlated variables and underlying data, factors that express what is common in the original variables, starting with linear combinations of the initial indicators and the main components, quantifying the components, showing the degree of contribution of each one to explain the behavior of the indicators that constitute the most important results of the analysis (Reis, 2001; Andrade, Meireles & Palácio, 2010).

First, the correlation matrix of the parameters evaluated at the starting point of each community and at the end was drawn up in order to extract the common factors with possible reduction of the parameters that determine the environmental sustainability. Therefore, the rotation of the axes relative to the common factors allows us to find a new set of variable weights for each component and the proportion of variance explained by each of these components remains constant with an orthogonal matrix, allowing different distribution, increasing the weight of the variables that contribute most and reducing the weight of those that contribute the least (Sands and Podmore, 2000, & Reis, 2001).

From the correlation matrix, one can verify the suitability of the set of variables to the statistical method, in order to extract the factors. The suitability of the data was evaluated by the Kayser Mayer Olkim method (KMO) (table 3), comparing the amplitude of the correlation coefficients observed with the partial correlation coefficients and, for KMO values <0.5 it is recommended that the model does not apply to the study (Norusis, 1990; Reis, 2001; Monteiro, & Pinheiro, 2004; Girão et al., 2007).

Table 3 – Suitability test applied to the Kaiser-Meyer-Olkin (KMO) model

KMO value	Application Model
1.00- 0.90	Very good
0.80-0.90	Good
0.70-0.80	Average
0.60-0.70	Reasonable
0.50-0.60	Bad
0.50	Unacceptable

Source: Adapted from (Norusis, 1990; Reis, 2001; Monteiro, & Pinheiro, 2004; Girão et al., 2007)

In this context, the orthogonal transformation procedure (Varimax) was used, in order to facilitate the interpretation of the extracted values, by means of a set of variable weights for each component, as well as the proportion of variance explained in each of them. Finally, the determination of the matrix of factor scores, through which it was possible to construct the index to rank the observations, using a simple or weighted sum of the scores belonging to the same observation. The factorial scores belonging to each factor have a normal distribution, with zero mean and unit variance, and can be used to indicate the value of each observation and the degree of importance expressed by the factor (Carneiro Neto, et al. 2008; Palácio, 2004, & Reis, 2001).

3 RESULTS AND DISCUSSION

Twenty-one variables were analyzed and the sensitivity test was performed by the Principal Component Analysis (FA/PCA) model and the preliminary procedures for matching the set of variables to the factorial analysis using the principal components method resulted in the elimination of some variables, being identified that only 8 (eight)factors presented some significance in explaining the total variance of the data.

The suitability test applied to the KMO model resulted in an index equal to 0.602, consideredacceptable, demonstrating that the model will promote a significant reduction in the dimension of the original data (Silveira and Andrade, 2002; Carneiro Neto, 2008). The number of components selected in this study was based on components that presented eigenvalues greater than 1, according to studies described by Hair Júnior et al. (2005) anddefined by the criterion of Keizer Guttman (eigenvalue > 1). The model of best fit, higher KMO and greater explicability of total variance, due to a smaller number of factors, wasthe three-component model.

The data rotation was generated to obtain values with greater acceptable orthogonality, since the main objective was to measure the components that exhibit the greatest influence on the system (Hawkins, 1974). The 8 (eight) components with an eigenvalue greater than 1, explain 99.9% of the variation of the data. From the analysis of the first three components, PC1, PC2 and PC3, it is verified that they explain 82.07% of the total variance, concentrating in three dimensions, explaining respectively 35.09 (table 4).

25.07 and 21.91% of the total data variance (Figure 2). In this work we chose to work with the first three components that explain 82.07% of the data, and identifying the variables that presented a correlation coefficient above 0.7.

The addition of components 4, 5, 6, 7 and 8 would explain only 17.83% of the data variance, which does not add significant information to the explanation of the result.

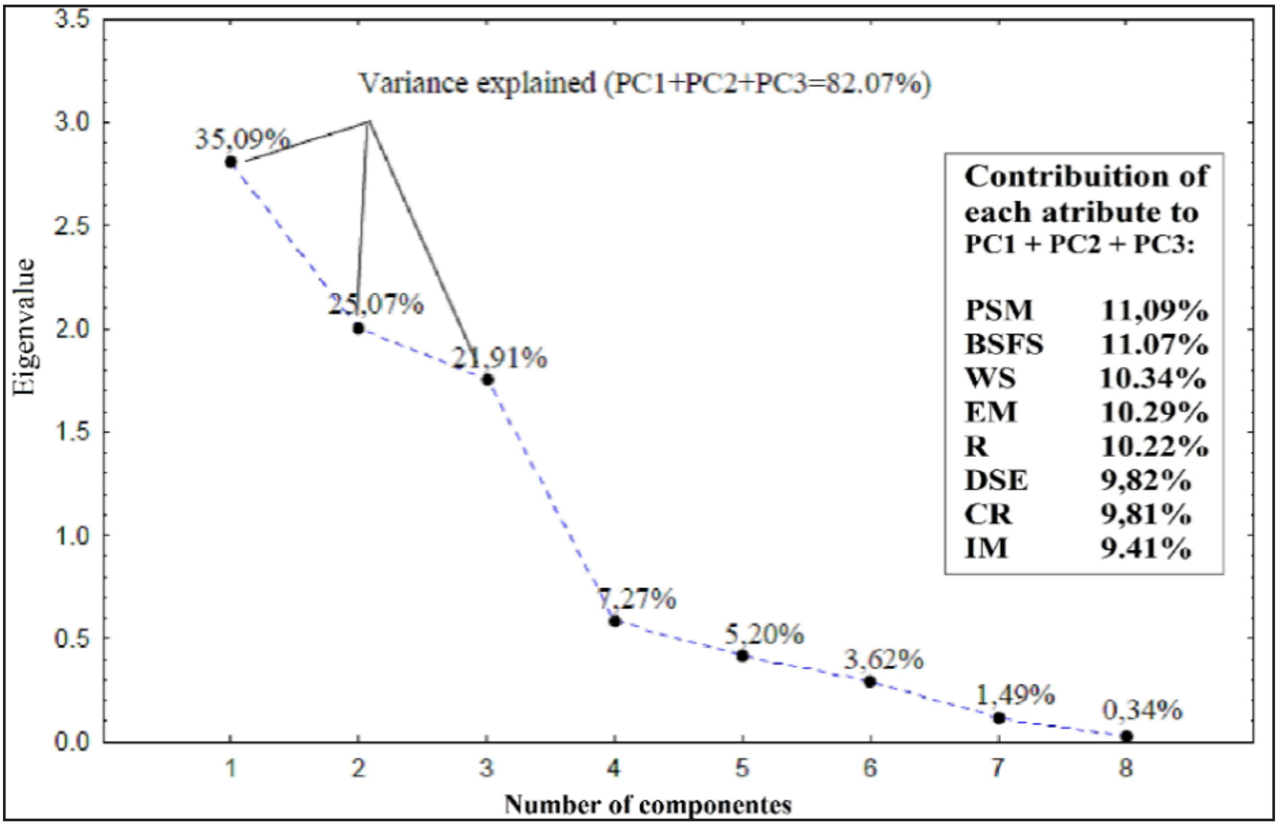
Table 4 – Matrix of factorial loads of the Communities of Cristolândia, Alto Crato and São Miguel

Variables	Components or Factors		
	PC1	PC2	PC3
Basic Services and Food Safety	0.762181	-0.175596	0.2190P52
Enterprise Management	0.827593	0.140783	0.106876
Information Management	0.783376	0.015112	-0.185921
Work Safety	0.080967	0.986536	0.013112
Contamination Risk	0.021516	0.986516	-0.015609
Degraded Soils Evaluation	-0.065613	0.004167	0.957290
Roads	0.840590	0.145778	0.080630
Production Systems Management	0.210523	-0.004881	0.942513
Var. Expl.	2.641742	2.018643	1.905625
Total Prop.	35.09%	25.07%	21.91%

Source: Authors (2018)

The first three components present indicators to meet the objectives of characterizing the investigated agroecosystems, allowing the identification of these production units. From the 82.07% of the total variance explained by the method, 35% is concentrated in the first component, demonstrating that agri-environmental sustainability presents differentiated dependence of the components defined by the applied model (Sands, & Podmore, 2000). Results similar to those presented were found by Luiz and Silveira (2000), Carneiro Neto, et al. (2008) and Andrade et al. (2009), where the values of the factorial weights for each component (PC1, PC2 and PC3) can be observed.

Figure 2 – Proportional variance of the data sets explained by the principal components and contribution of each variable to the total variance explained by the Screeplot method of the Communities of Cristolândia, Alto Crato and São Miguel



Source: Authors (2018)

It should be noted that the order of the generated factors shows their importance as well as their intrinsic characteristics, and each weight explains the relationship between the component and the variable, allowing the identification of variables with greater interrelationships in each component, and the eigenvalues of the factorial weights indicate which are the most significant variables in each component, demonstrating that the three maincomponents have characteristic roots larger than one, with values, respectively, equal to 2.80; 2.00 and 1.75.

Component 1 explains 35.09% of the data variation and is positively correlated withthe variables Basic Services and Food Safety (BSFS), Enterprise Management (EM), Information Management (IM) and Roads (R), which presented correlation weight above 0.76 and is negatively correlated with the Degraded Soil Evaluation (DSE) variable, indicating that these variables are more significant for the PC1 component, and the variable that has the greatest influence is the Roads variable. In general, this component can be characterized as being correlated with the conditions of transportation logistics, animportant factor for basic essential services such as: family health, education, electricity, treated water, selective waste collection, and products and services. associated with the proper administration of the property.

The results of the field survey indicated that there is a precariousness of the roads in the three systems studied, 28.75% of the stretches of roads impassable in winter, 56% of the roads in precarious conditions due to lack of maintenance by the public power, presenting itself as a limiting factor of productivity, since only 15.25% of the roads are in good state of conservation for locomotion and drain the production being configured as a necessity and a condition to increase the productivity.

The field research found that the Enterprise Management makes a diversification of production with a variety of products that make up the citizens' table. The data show that 57.5% of the producers do not have the physical and accounting control of their production, 33.75% have some control of the accounting of the inputs and products sold and only 8.75% have the physical and accounting control of the production and the flowof individual or joint production is associated with the financial condition of the rural producers, leaving the producers with less economic power totally dependent on the middlemen. Similar results were found by Andrade et al. (2009), in sustainability classification studies of the agricultural production units in the Irrigated perimeter ArarasNorte, Ceará, Brazil.

The data obtained in the field on the management of the information allow to conclude that 36.25% of the producers do not seek information related to the increase of the productivity and forms of commercialization of the products produced, 18.75% partially seek information, but they can not implement in their business and 45% seek information on productive techniques and increase productivity, with implementation in their businesses, optimizing production and reaching other consumer markets.

Thus, agroecosystems have been able to produce products in all systems, showing a diversification of the products produced necessary for the maintenance of the life in the field, guaranteeing the minimum necessary consumption, being limited by the offer of basic services of health and education, where 56.25% are offered in poor conditions and 43.75% are offered in good condition to producers. This is often due to the limitation of road conditions which is a limiting factor in offering essential basic services and transporting products and services to the consumer markets.

Therefore, Component 2 explains 25.07% of the total data variation and is positively correlated with the variables Workp Safety (WS) and Contamination Risk (CR) and, have a correlation weight greater than 0.98, which indicates the importance of the use of Personal Protective Equipment (PPE), in the use of pesticides and herbicides in the crop, in order to avoid contamination, the variable correlates negatively with the variablesBasic Services and Food Safety (BSFS) and Production Systems Management (PSM). The variables BSFS and PSM represent the concern with the safety in the work, by the producers that apply chemicals in the control of plagues.

The results of the field research show that more than 70% of the producers are aware of the need to use PPE and are aware of the need to preserve natural resources, using less invasive pest control and opportunistic plants. producers of the three production systems to use PPE in order to prevent accidents, only 8% of producers reported using pesticides and herbicides to control pests and spontaneous herbs and, as expected, application of the product according to the manufacturer's recommendations, in order to avoid contamination of productive areas and water sources.

The Agricultural Census 2006 shows that, as the number of years of the producer increases in the administration of the agricultural establishment, the option for the use of pesticides increases, in turn, the establishments that develop organic or agroecological agriculture practices, which obtained low adoption between establishments, representing less than 1.7% of the total number of rural establishments (IBGE, 2016).

Finally, Component 3 explains 21.91% of the total data variation and is positively correlated with the variables Degraded Soil Evaluation (DSE) and Production System Management (PSM) and have a correlation weight greater than 0.94, which indicate that the proper management of production systems avoids soil degradation and correlates negatively with the variables Information Management (IM) and Contamination Risk (CR). These variables are directly related, since soil degradation is the result of the adoption of soil protection management techniques against erosion (mulching, straw use, forage utilization, crop rotation), in order to avoid soil is degraded and depleted by leaching.

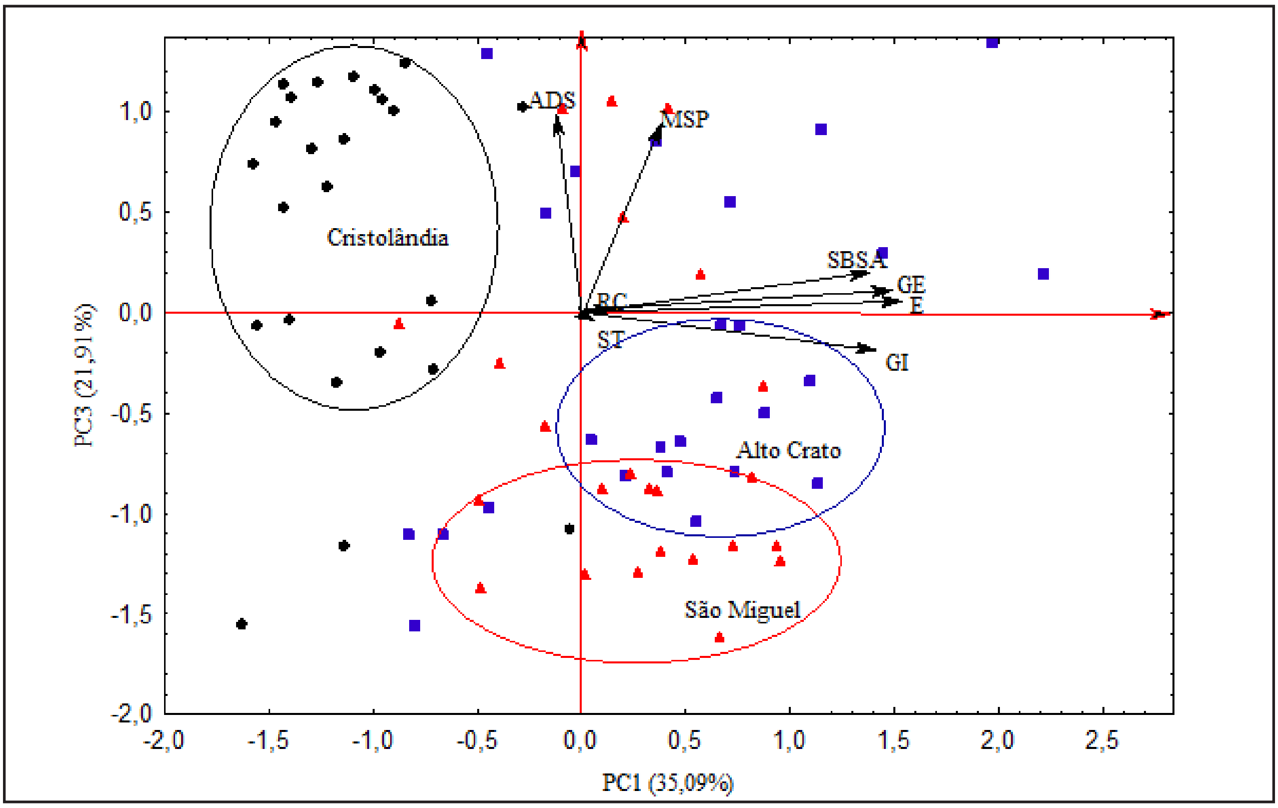
The results of the field research show that 35% of the producers have empirical knowledge of soil protection techniques in order to avoid exhaustion, that they are degraded and impoverished, 15% of the producers know the techniques and practice with some limitation. It is pertinent to say that 45% of the producers put into practice the techniques of conservation in a partial way and 5% of the producers exploit the properties in a disorderly way leaving the soil susceptible to erosion, degradation, exhaustion and become degraded and impoverished. Some systems need to improve, management techniques, with implementation of crop rotation, integrated management, land cover utilization, green manuring and plant consortium, so that there is a longer productive system, with the implementation of management in areas where there was disorganized exploitation, a fact confirmed in the 2006 Census of Agriculture (IBGE, 2016).

The characterization of the systems was done through the Biplot of the scatter plot where the values of Component 1 versus Component 3 were plotted, for each of the properties belonging to the Cristolândia, Alto Crato and São Miguel systems (Figure 3).

Component 1 (PC1) is characterized by the indicators Management of Establishment, Information Management, Basic Services and Food Security and

Roads (EM, IM, BSFS and R). Component 3 PC3 is characterized by the Degraded Soils Evaluation and Management of Production Systems (DSE and PSM).

Figure 3 – Biplot PC1 x PC3 on sustainability in the Cristolândia, Alto Crato and São Miguel systems by ACP



Source: Authors (2018)

Component 1, has a positive correlation with the High Crato system, but negatively correlated with Cristolândia system, the higher the value of these variable is better is the performance of the High Crato system and the worse the performance Cristolândia. In addition, the PC3 (DSE and PSM) component correlates positively with the Cristolândia system, but correlates negatively with the São Miguel system, that is, the higher the value of these variables the better the performance of Cristolândia and the worse the performance of the São Miguel system.

It can be observed (Figure 3) that the first CP1 component (EM IM, BSFS and E) is positively correlated with the Alto Crato system and negatively with the Cristolândia system, indicating that these variables are more significant for the PC1 component, and the variable that has the greatest influence for PC1 is the roads variable. This component is related to the conditions of transportation logistics, an important factor for basic essential services such as: family health, education, electricity, treated water, selective garbage collection and products and inputs to be transported, associated with good property management.

Next, the third Component, PC3 (DSE and WS) correlates positively with the Cristolândia system and correlates negatively with the São Miguel system, indicating that the proper management of natural resources is necessary to revert the existing degradation framework once that productive systems based exclusively on the use of fertilizers, agricultural pesticides, seeds and the use of soil preparation machines, proved unsuitable and unsustainable for tropical regions, and it is necessary to develop production systems adapted to the local reality, with a minimum of impact on the environment and draws attention to the use of personal protective equipment, especially when applying herbicidesto the crop.

The Principal Component Analysis applied to the study showed the differences related to the three systems (Figure 3), although they are inserted in the same environment. As expected, they are similar in relation to the descriptors, with significant weighting factors, being that the community of Cristolândia (2nd and 3rd quadrant) is more homogeneous than the communities of Alto Crato and São Miguel (3rd and 4th quadrant) indicated by the distance between the components (Figure 3).

In the same way, when analyzing the descriptors that most influenced the discrimination of the groups, it is observed that the Alto Crato system is characterized by presenting the best roads, the best Management of the Enterprise, the best Information Management, as well as the best Basic Services and Food Safety, enabling better logistics conditions, so that essential services become present and producers can transport products and inputs for production.

Due to the better organization of this community, it is possible to claim better conditions for working with the public authorities, since it has an active association

(Association of Producers of Fruit and Vegetable Producers of the Vicinal of Alto Crato) and recently it was contemplated with agreements with the public power for the acquisition of machines and equipment for production and has reached other consumer markets, through the institutional purchase of family farmers, taking advantage of the benefits granted by Law 11,947 of June 16, 2009 (Brazil, 2009), enabling its members to increase productivity by having the machines and equipment needed to work the land and guaranteed demand for the products produced, improving income, living conditions in the field and the sustainability of the agroecosystem.

The Cristolândia system presented the best management of natural resources and the best measures of safety at work. It was demonstrated that the adequate management of natural resources contribute to the longevity of agroecosystem productivity, associated with work safety, the proper use of Personal Protective Equipment and the use of agroecological techniques to control pests and invasive plants.

4 FINAL REMARKS

The detailed study of the agroecosystems identified that these presented different behaviors regarding their level of sustainability, presenting critical points such as, Degree of Indebtedness, Quality of Generated Employment, Education and Training, Quality of Employment Generated, Information Management, Work Safety, Contamination Risk, Landscape Diversification, Systems Management and Production and Staying in Agriculture.

The study showed the Roads indicator as the most influential variable in the formation of the main components due to similarities between agroecosystems, an aspect that ensures their condition for use in future evaluation works with these agroecosystems. It should be noted that this is an initial study with these agroecosystems, and there is a need for complementary studies that involve other aspects of sustainability, such as soil attributes, water quality and economic feasibility studies.

Finally, the Principal Component Analysis portrays the reality of the studied communities, since the Alto Crato System proved to be more sustainable than the other systems, presenting a sustainability index of 0.63, while the Cristolândia and São Miguel systems presented a corresponding index at 0.59 and 0.58, respectively. The Alto Crato System has a better infrastructure of roads, to drain the production and to allow accessibility of the essential services, better organization, with active association of producers (Association of Producers of Hortifrutigranjeiros of Vicinal of Alto Crato), which made it possible to sign agreements with the public power to purchase machinery and equipment for production and to reach other consumer markets for products from family agriculture, through the institutional purchase of family farmers, taking advantageof the benefits granted by Law 11,947 of June 16, 2009, making it possible to increase productivity and consequently the income of producers, because they have the machines and equipment necessary to work the land and have guaranteed demand for the products,improving the living conditions in the field.

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