

Agriculture and sustainable landscapes: agricultural diversification in the state of Minas Gerais, Brazil

*Agricultura e paisagens sustentáveis: a diversidade
produtiva do setor agrícola de Minas Gerais, Brasil*

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ABSTRACT

The intensification of agricultural production and its impact has been widely discussed around the world. Agricultural diversification is a possible path to promote sustainability in agriculture, considering ecological and socioeconomic aspects. Thus, this paper aims to develop an indicator that could assess the agricultural diversification of the municipalities of Minas Gerais, to understand the dynamics of agriculture in the state. Our results show that most of the municipalities (76%) presented a “high” or “very high” diversification, and it can be explained by the strong presence of family farming. However, the share of the gross domestic product (GDP) of these municipalities relative to agriculture activity is relatively low, highlighting that economic sustainability has not been fully achieved yet. In addition to the producer’s interest in increasing agricultural diversification, it is important to ensure a rural development public policy fostering diverse agricultural production systems aligned with environmental sustainability standards.

Keywords: Agriculture Diversification. Simpson Diversity Index. Sustainable landscapes. Governance.

RESUMO

A produção de alimentos é importante para garantir a segurança alimentar, e os diferentes modos de produção podem gerar diferentes impactos ambientais. A diversificação agrícola é considerada uma das formas de promover a sustentabilidade, tanto em termos ecológicos quanto socioeconômicos. Para compreender a dinâmica da agricultura em Minas Gerais, este trabalho utiliza um indicador para caracterizar os sistemas de produção agrícola e avaliar a diversidade produtiva dos 853 municípios do estado. A maior parte dos municípios (76%) apresentou uma diversidade alta ou muito alta, sendo esta associada principalmente ao contexto da agricultura familiar. No entanto, a contribuição desses sistemas agrícolas diversificados para a economia dos municípios é relativamente baixa, mostrando que a sustentabilidade econômica de sistemas diversificados ainda é um desafio. É importante que, além do interesse do produtor, exista uma política pública de desenvolvimento rural capaz de viabilizar sistemas de produção agrícola alinhados com padrões de sustentabilidade ambiental.

Palavras-chave: Diversificação Agrícola. Índice de Diversidade de Simpson. Paisagens Sustentáveis. Governança.

1 INTRODUCTION

Food demand increases as the world population grows, and the scenario foreseen for the coming years is not encouraging: United Nations (UN) estimates that 11.2 billion people will be living on the planet in 2100 (UN, 2017). This perspective calls for agricultural systems able to supply food and economic needs of an increasing population.

In this context, the process of agriculture intensification stands out, which aims to increase the amount of food produced per unit area (productivity), especially with the use of technologies that allow large-scale production, generally using monoculture as a way of production. In addition to food, monocultures are also intended for biofuel production, which production is increasing year after year (IEA, 2019). Considering only the Brazilian sugarcane production destined for the sugar-energy sector, 8.6 million hectares were harvested during 2018/2019 (BRASIL, 2019), this corresponding to 85% of the total sugarcane planted area in the country (IBGE, 2019a). This reinforces the prominent position that agribusiness holds in the Brazilian economy.

The expansion to new agricultural areas and the intensification of existing areas would contribute to the increase in production fulfilling this rising demand (TILMAN et al., 2011). However, it is known that many environmental impacts are associated with agricultural activity, especially monocultures such as soil degradation and eutrophication (KASTNER, KASTNER and NONHEBEL, 2011), biodiversity loss (PERFECTO and VANDERMEER, 2010), greenhouse gas (GHG) emissions due to changes in land use and the use of fertilizers (BURNEY, DAVIS and LOBELL, 2010), among others.

Currently, several regions in the world are dominated by monocultures, which replace ecosystems that were previously marked by a high richness of species. In this way, agriculture was largely responsible for simplifying and homogenizing diverse ecosystems around the world (TILMAN, 1999).

One of the technical proposals to reduce landscape simplification and homogenization is the promotion of agricultural diversification (KASSAM and FRIEDRICH, 2012), which can be done through the integration of two or more agricultural activities (plant species) in the same rural property (SANTANA, FERREIRA E ALENCAR, 2009). It can reduce the risks of monoculture as the main source of income for the producer and increase both economic and landscape sustainability. Regarding family farming, there is a number of advantages associated with agricultural diversification: increase in marketing possibilities throughout the year, rescue of traditional product crops, increase in incomes and the improvement in living conditions of the family as a whole (BARBOSA ET AL. 2016; HAAS, 2008).

Michler and Josephson (2017), for example, assessed the impact of agricultural crop diversification on families from the most disadvantaged regions in Ethiopia. By analyzing official statistical data in the country, they were able to quantify that families with diversification of crops in their properties have, on average, lower poverty rates. In addition, it has been found that the diversification of agricultural production reduces the probability that an economically weak family will fall into poverty. In a similar context, Waha et al. (2018) state that, at the family level, agricultural diversification is more successful in ensuring food security.

The concept of sustainability has been widely discussed and adopted for environmental issues in recent decades. However, it has been overlooked in the context of the landscape. Sustainable landscapes, according to the International Institute for Sustainability, are those that take on the challenge of reconciling social, economic and ecological interests, by integrating them into territorial planning processes at different scales from urban areas to rural areas and from pristine to degraded areas

(IIS, 2015). Specifically dealing with the rural environment, the sustainability of landscapes aims to establish conditions for biodiversity conservation and development of productive activities to be combined in common areas.

Considering the context of sustainable agriculture and the importance of using indicators that are able to assess landscape sustainability, it is necessary to formulate metrics that quantify landscape aspects related to socioeconomic and environmental dimensions. As diversification of agricultural production is one of the possibilities to increase sustainability of rural landscapes, it is important to propose indicators that are able to assess diversification of agricultural production at the municipality level.

2 DIVERSIFICATION OF AGRICULTURE IN MINAS GERAIS

Agriculture has great relevance in the historical and economic context of Minas Gerais. Agricultural practices are closely related to the development of mining in the state, from the 18th century onwards, but initially as a subsistence activity. The activity only gained a prominent position with mining decline, when new markets for agricultural products emerged, in the course of the 18th century (MINAS GERAIS, 1978).

Minas Gerais' agriculture once again gained great importance at the beginning of the Brazilian republican period, when coffee production became one of the main pillars of the country's economy. Later, the state aimed to diversify production, in order to consolidate a strong agricultural sector, capable of sustaining a vigorous industrialization process (GARCIA AND ANDRADE, 2007).

In the current scenario, agriculture still has great importance in the socioeconomic context of Minas Gerais. According to data from MapBiomas, agriculture areas increased over a short period of time: from approximately 635,000 ha in 1985 to 3,575,000 ha in 2018 (PROJETO MAPBIOMAS, 2020). In addition, agribusiness GDP accounted for 33.5% of the state's total GDP (EMATER, 2018).

According to 2017 Agricultural Census, Minas Gerais has 607,557 rural establishments, and they occupy approximately 65% of the state's territory (IBGE, 2019b). Family farming has also a great importance in Minas Gerais: data from the same census indicate the existence approximately 440,000 family establishments in the state, which corresponds to 73% of the total rural establishments in Minas Gerais (IBGE, 2019b).

Considering the relevance of family farming in Minas Gerais scenario, the state also gains prominence when diversification of agricultural production is analyzed. According to the 2018 Municipal Agricultural Production Survey, Minas Gerais is the state with the largest variety of crops (temporary and permanent) in Brazil: out of 71 crops analyzed in the survey, 52 were found in the state (IBGE, 2019a). However, the specific effects of diversification are not yet widely understood, so the incentive for this practice has not yet reached its full potential.

Thus, this work aims to quantify the agricultural diversity of each one of the municipalities of Minas Gerais through a consistent indicator. We also aim at assessing how agricultural diversity is associated to other socioeconomic and environmental indicators.

3 METHODS

3.1 DATA COLLECTION

Data used in this study was collected in Municipal Agricultural Production Survey (IBGE, 2019). We first estimated the planted area for each agricultural crop. We used only those cases whose quantity produced was at least one ton and distributed over at least one hectare. For this purpose, it was used

average values (2014 to 2018), in order to reduce the exceptionalities that may have occurred in some years of the historical series. With these data, it was possible to calculate the agricultural diversity index for each municipality using the Simpson index, as described in section 3.2.

Then, this data was compared to other variables that allow to outline the productivist and conservationist profile of the municipalities of Minas Gerais. The following variables were selected:

- Percentage of anthropized area by municipality;

The percentage of anthropized area measures the degree of human intervention in landscapes. As agricultural production requires an available area for its development, it is assumed that the increase in the anthropized area is related to the productive aspect of the municipalities. To this purpose, it was used database (shapefile) containing land uses, from Brazilian Foundation for Sustainable Development (FBDS)(FBDS, 2018).

- Contribution of agriculture to the municipal Gross Domestic Product (GDP);

The share that agricultural activity adds to the municipal GDP is an important indicator of the size of this sector in the local economy. The higher the value, the greater is the predominance of the activity, which shows a strong productive aspect of the municipalities. This same indicator was used by Pinto Correia et al. (2016) to assess the productive dimension of human occupation in rural spaces. To calculate this indicator, it was considered the percentage of added value of agriculture at municipal GDP over the total GDP (IBGE, 2016).

- Euclidean nearest-neighbor distance (forest fragments)

Euclidean nearest-neighbor distance is one of the landscape metrics used to assess landscape fragmentation - in this case, forest fragmentation. It can cause several negative consequences, such as habitats and biodiversity loss, changes in ecological interactions, among others (SOUZA et al., 2014). The greater the distance between fragments, the greater the degree of isolation verified, which is detrimental to biodiversity conservation. In this study, the analysis of the Euclidean nearest-neighbor distance of fragments used available data from FBDS database (FBDS, 2018), and performed on FRAGSTATS 4.2.1 software.

- Average size of forest fragments;

The average size of forest fragments is another landscape metric used to assess fragmentation - larger fragments are usually better for promoting connectivity and biodiversity conservation (VALENTE E VETORAZZI, 2005). It is important to note, however, that the total area of the fragment was considered, including border area. As the scale of this study involves all municipalities in Minas Gerais, encompassing different biomes and ecosystems, it was considered inappropriate to assume a single border value for all areas. Thus, only the structural element of the landscape was considered, without considering its functional aspect. Once again, average size of the fragments of forest areas was calculated using FBDS database and was performed in FRAGSTATS 4.2.1 software.

- Percentage of permanent protection areas by municipality;

Permanent protection areas (PPAs) are instituted through specific legal regulations, (BRASIL, 2012). PPAs were adopted as a surrogate for the conservationist profile of the municipalities as it is a common factor to all of them. Shapefiles containing these areas are available in FBDS database. It is important to note, however, that these areas are related only to riparian areas.

3.2 CALCULATION OF THE AGRICULTURAL DIVERSITY INDEX OF THE MUNICIPALITIES

With variables previously calculated, the productive diversity of each municipality was calculated using the Simpson Diversity Index (SID) (SIMPSON, 1949), using the following equation:

$$SID = 1 - \sum_{i=1}^N \left(\frac{X_i}{\sum_{i=1}^N X_i} \right)^2$$

Where: X_i = occupied area by each product and N = number of agricultural products in the municipality that occupy more than one hectare and whose quantity exceeds one ton.

This index ranges from 0 to 1, with 0 being the municipality that presents only one type of agricultural production, and increases to the value of 1 as diversity increases.

The values obtained for each municipality were associated with a geographic database (shapefile of municipalities in Minas Gerais), in order to generate a map of agricultural diversity.

The municipalities were grouped into five distinct classes:

- Very low diversification: $SID \leq 0.20$;
- Low diversification: $SID > 0.20$ e ≤ 0.40 ;
- Medium diversification: $SID > 0.40$ e ≤ 0.60 ;
- High diversification: $SID > 0.60$ e ≤ 0.80 ;
- Very high diversification: $SID > 0.80$.

3.3 STATISTICAL ANALYSIS

First, the normality of data was verified, using Kolmogorov-Smirnov test. After this verification, descriptive statistics of data and the correlation between the agricultural diversity and the other analyzed variables were calculated. All analyzes were performed on SPSS 19 statistical software.

4 RESULTS AND DISCUSSION

Table 1 shows values of descriptive statistics, while Figure 1 shows the distribution of the calculated values for the agricultural diversity index.

Table1 | Descriptive statistics of the analyzed variables

<i>Variable</i>	<i>Number of occurrences</i>	<i>Minimum value</i>	<i>Maximum value</i>	<i>Average</i>	<i>Standard deviation</i>
SID	853	0.00	0.88	0.66	0.13
CONTRIBUTION OF AGRICULTURE TO THE MUNICIPAL GROSS DOMESTIC PRODUCT (GDP)	853	0.00	0.72	0.17	0.12
PERCENTAGE OF ANTHROPIZED AREA	853	0.09	0.94	0.67	0.16

Variable	Number of occurrences	Minimum value	Maximum value	Average	Standard deviation
AVERAGE SIZE OF FOREST FRAGMENTS; (HA)	853	1.02	70.30	6.32	5.53
EUCLIDEAN NEAREST-NEIGHBOR DISTANCE (FOREST FRAGMENTS) (M)	853	25.40	246.64	62.76	22.85
PERCENTAGE OF PERMANENT PROTECTION AREAS BY MUNICIPALITY;	853	0.01	0.61	0.11	0.05

Source: Elaborated by the author.

According to results of socioeconomic variables presented in Table 1, contribution of agricultural activity to the municipal GDP of the 853 municipalities in Minas Gerais ranges from 0 to 72%, while the anthropized area varies from 0.9 to 94%. Regarding the results of landscape metrics, Table 1 shows that the average area of forest patches varies from 1 to 70.3 hectares, with mean and standard deviation being 6.32 and 5.53, respectively. For Euclidean nearest-neighbor distance between forest fragments, average values per municipality range between 25 and 246 meters. Finally, Table 1 shows that, on average, Minas Gerais municipalities have 11% of their territory in riparian permanent protection areas.

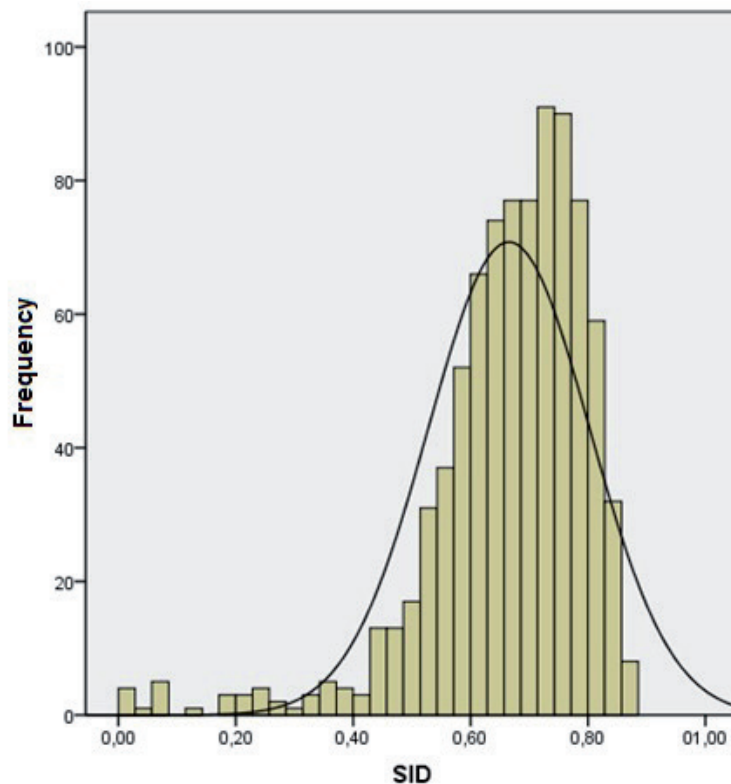


Figure 1 | Distribution of calculated values for agricultural diversity

Source: Elaborated by the author.

Also according to Table 1, the average and standard deviation of the agricultural diversity index of the 853 municipalities in Minas Gerais is of 0.66 ± 0.13 . After calculating the index for each one of the municipalities, it was found that 1.6% of Minas Gerais municipalities are classified as having a very low agricultural diversity, 2.6% as low diversification, 19.5% as medium diversification, 64.7% as high diversification and 11.6% have very high diversification.

Figure 2 shows the map with the classification of agricultural diversity in the municipalities of Minas Gerais. In the group with the lowest values for agricultural diversification, there is a strong concentration in Triângulo Mineiro region. This can be explained by the exploitation of agribusiness that takes place in the region, developed by medium and large-sized rural entrepreneurs who make intensive use of technology, making this agricultural region the most dynamic and developed in the state (BASTOS E GOMES, 2011).

Other municipalities are dispersed in several regions of the state, and a possible explanation for the low diversification may be related to the fact that agriculture is not one of the main economic activities developed in these areas (IBGE, 2016b). In this group, Belo Horizonte (capital of the state) stands out, as no information on agricultural production was verified. So, the calculated index assumed zero value.

Geographic factors may also be an explanation for the different levels of diversification observed in Minas Gerais. There is, for example, in the intermediate region of Juiz de Fora, a strong concentration of municipalities classified with a medium diversification. This can be explained by topography of the rugged relief and land forms with steep slopes present in the region, which can be considered an obstacle to agricultural production, with the most fertile areas being limited to the region's valleys (BASTOS E GOMES, 2011).

The two categories of municipalities with the highest values for the diversity index cover 651 municipalities (76.3% of the total municipalities in Minas Gerais), which are homogeneously distributed in the state. These results reinforce the importance of Minas Gerais in the Brazilian agricultural scenario, and also indicate the relevance of family farming in the state, since diversification is a practice intrinsically associated with this type of production.

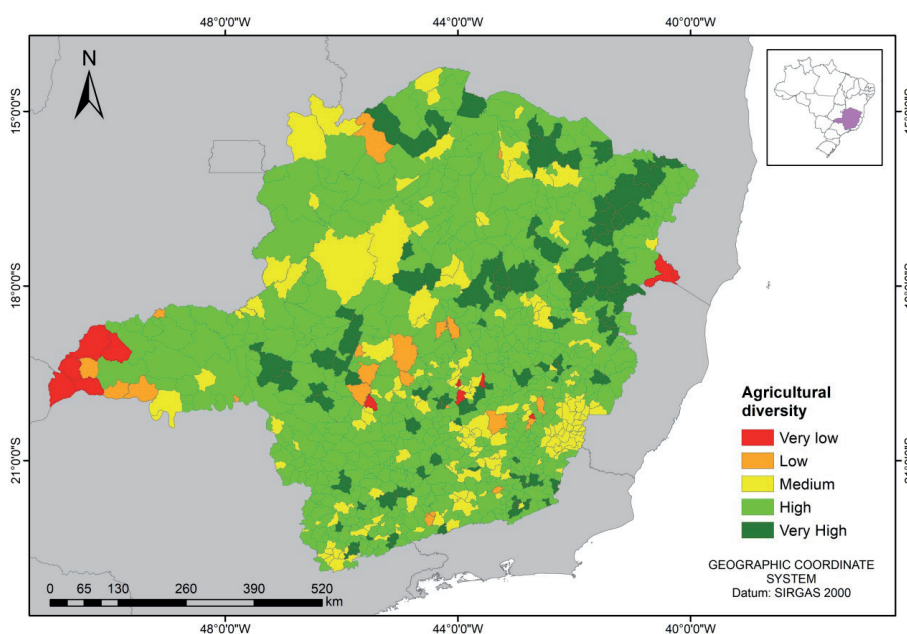


Figura 2 | Agricultural diversity in the state of Minas Gerais

Source: Elaborated by the author

It is important to understand, however, how agricultural diversity is reflected in production and conservation aspects in the state. For this purpose, a statistical analysis was performed, and it was verified that data do not follow normal distribution, which implies the choice of Spearman's correlation coefficient to verify which is the relationship between the variables. The detailed results of correlation amongst variables are found in Annex 1.

Our results show that there is no significant correlation ($\alpha = 0.05$) between the index of agricultural diversity and the variables: average size of forest fragments, percentage of permanent protection areas by municipality; contribution of agriculture to the municipal Gross Domestic Product (GDP) and percentage of anthropized areas by municipality.

The only significant correlation obtained among the variables analyzed was related to the variable "Euclidean nearest-neighbor distance (forest fragments)". It was found that the increase in the

diversification index is related to the decrease in the Euclidean nearest-neighbor distance (forest fragments), as shown by the negative value for the correlation (-0.073). Although the value obtained is not high, this result can be considered an indication that agricultural diversification may be positively associated with increased connectivity between forest fragments (without considering specific focus groups), which favors biodiversity conservation. Annex 2 shows the difference between the averages of the variables analyzed for each one of the five groups of agricultural diversification.

The map in Figure 3 shows how the municipalities classify in relation to the variable “Euclidean nearest-neighbor distance (forest fragments)”. The shorter the Euclidean nearest-neighbor distance, the greater the likelihood of biodiversity conservation taking place, as the isolation of fragments has a negative effect on species richness, decreasing the (potential) rate of immigration or recolonization (ALMEIDA, 2008). As a result, from an ecological point of view, there is an increase in the landscape sustainability.

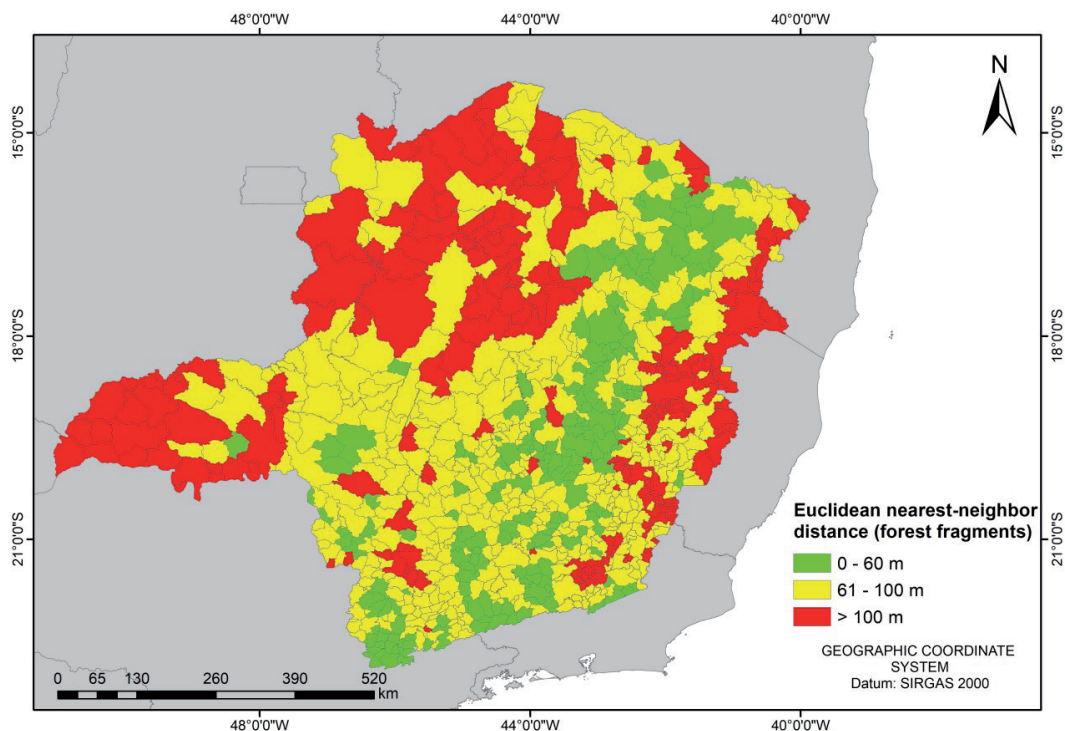


Figure 3 | Spatial distribution of the variable “Euclidean nearest-neighbor distance (forest fragments)”.

Source: Elaborated by the author.

In general, it seems that the increase in agricultural diversity positively impacts landscape in terms of conservation; however, when assessing social aspect of landscapes, related to agricultural production and the income generated from it, agricultural diversity does not yet have a significant influence in terms of improving economic indicators, which directly raise the issues of reconciling ecological and economic sustainability.

It is important to highlight that, in this work, it was discussed exclusively the concept of agricultural diversity, while another concept is important to explain the productive dynamics of rural environments: rural diversification, which consists of combining, in addition to agricultural activities, other non-agricultural activities, in order to explore all the potential that the property / region has. Some authors (SILVA, 2001 apud SANTANA, FERREIRA AND ALENCAR, 2009) point out that the diversification of agriculture itself is not able to promote an increase in income sufficient to reduce the dependence of producers in relation to local labor markets, which it may justify the low correlation between the agricultural diversity index and economic variables.

Even though agricultural diversification has the producer as one of the main social actors, it is highlighted that the success of this action does not depend exclusively on producers themselves. It is necessary to have an associated rural development policy, so it will be possible to generate a complex chain of reciprocal interactions between all axes (credit, agricultural research, technical assistance and rural extension), thus guaranteeing access to land and technologies for production and sustainable management of establishments (BITTENCOURT, 2002 apud SANTANA, FERREIRA E ALENCAR, 2009). Therefore, it is evident that the achievement of sustainable landscapes through agricultural diversification must be the result of actions of several sectors of society, with the public sphere (municipal and state governments) playing a fundamental role in the fostering of agricultural diversity.

5 FINAL CONSIDERATIONS

The development of sustainability strategies in rural areas has proved to be a great challenge, since the concept of landscape sustainability has had difficulties in assuming a relevant role, given the inherent complexity of its management process. One of several challenges is the development of metrics to track progress and enable landscape management. Throughout this paper, the agricultural diversity index was calculated, in order to classify municipalities of Minas Gerais. It was found that most municipalities in the state (76.3%) were classified as having a “high” or “very high” agricultural diversity, which confirms the state’s position as the most diversified in the country. However, this diversification is not yet fully reflected in economic and environmental indicators, which shows that there is still a need to implement a series of actions that, in fact, target to guarantee landscape sustainability, both in environmental and economic aspects. Considering that each municipality presents a particular reality (with problems and strengths), it is desirable that different portfolios of public policies are developed, targeting different local identities that guarantee the involvement of all actors in order to generate long lasting results.

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ANNEX 1 – CORRELATION ANALYSIS BETWEEN VARIABLES

Correlations								
			SID	Average size of forest fragments (ha)	Euclidean nearest-neighbor distance (forest fragments) (m)	% of permanent protection areas by municipality	Contribution of agriculture to the municipal Gross Domestic Product (GDP)	% of anthropized area by municipality
SPEARMAN'S RHO	SID	Correlation Coefficient	1,000	,003	-,073*	-,063	-,055	-,056
		Sig. (2-tailed)	.	,928	,034	,068	,107	,101
		N	853	853	845	853	853	853
	AVERAGE SIZE OF FOREST FRAGMENTS (HA)	Correlation Coefficient	,003	1,000	-,168**	-,107**	-,189**	-,558**
		Sig. (2-tailed)	,928	.	,000	,002	,000	,000
		N	853	853	845	853	853	853
	EUCLIDEAN NEAREST-NEIGHBOR DISTANCE (FOREST FRAGMENTS) (M)	Correlation Coefficient	-,073*	-,168**	1,000	-,092**	,111**	,533**
		Sig. (2-tailed)	,034	,000	.	,007	,001	,000
		N	845	845	845	845	845	845
	% OF PERMANENT PROTECTION AREAS BY MUNICIPALITY	Correlation Coefficient	-,063	-,107**	-,092**	1,000	-,134**	,040
		Sig. (2-tailed)	,068	,002	,007	.	,000	,242
		N	853	853	845	853	853	853
	CONTRIBUTION OF AGRICULTURE TO THE MUNICIPAL GROSS DOMESTIC PRODUCT (GDP)	Correlation Coefficient	-,055	-,189**	,111**	-,134**	1,000	,165**
		Sig. (2-tailed)	,107	,000	,001	,000	.	,000
		N	853	853	845	853	853	853
	% OF ANTHROPIZED AREA BY MUNICIPALITY;	Correlation Coefficient	-,056	-,558**	,533**	,040	,165**	1,000
		Sig. (2-tailed)	,101	,000	,000	,242	,000	.
		N	853	853	845	853	853	853

*. Correlation is significant at the 0.05 level (2-tailed).

**.. Correlation is significant at the 0.01 level (2-tailed).

Source: Elaborated by the author.

ANNEX 2 – DESCRIPTIVE STATISTICS OF ANALYZED VARIABLES BY DIVERSIFICATION GROUP

<i>SID Group</i>		<i>Average size of forest fragments (ha)</i>	<i>Euclidean nearest-neighbor distance (forest fragments) (m)</i>	<i>% of permanent protection areas by municipality</i>	<i>Contribution of agriculture to municipal GDP (%)</i>	<i>% of anthropized area by municipality</i>	<i>Number of cultures (units)</i>
VERY LOW	AVERAGE	5.43	100.11	8.41	13.69	69.36	7.64
	MEDIAN	5.84	117.84	7.17	9.24	81.96	8.00
	STANDARD DEVIATION	2.12	47.01	3.94	13.79	23.99	5.06
LOW	AVERAGE	5.28	72.03	10.89	20.61	73.17	11.27
	MEDIAN	4.38	63.51	11.32	18.79	78.96	11.00
	STANDARD DEVIATION	3.22	24.84	5.66	12.87	15.20	5.62
MEDIUM	AVERAGE	5.80	64.33	12.68	17.50	69.02	11.21
	MEDIAN	4.76	59.02	13.16	17.18	71.98	11.00
	STANDARD DEVIATION	3.36	23.93	4.07	11.31	13.56	4.64
HIGH	AVERAGE	6.29	61.43	11.47	17.24	67.23	13.86
	MEDIAN	4.79	57.06	11.23	15.15	71.62	13.00
	STANDARD DEVIATION	5.61	21.00	4.87	11.73	16.27	4.95
VERY HIGH	AVERAGE	7.72	60.13	11.86	16.11	62.85	15.36
	MEDIAN	5.53	53.64	11.02	12.26	68.95	15.00
	STANDARD DEVIATION	8.00	20.65	7.07	13.32	20.13	4.52

Source: Elaborated by the author.