Engenharia Agrícola

ISSN: 1809-4430 (on-line)

www.engenhariaagricola.org.br

Doi: http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v40n3p280-288/2020

GRAIN STORAGE SYSTEM IN THE STATE OF PARANÁ, BRAZIL, FROM THE PERSPECTIVE OF MULTIVARIATE ANALYSIS

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KEYWORDS

agribusiness, association, cophenetic correlation coefficient, category of storage capacity, clustering, dissimilarity measures.

ABSTRACT

This study aimed to identify whether there is an association between types of storage and categories of commercialization and use of grains, group the types of storage with the categories of commercialization, and group static and dynamic capacities of the units in the state of Paraná, Brazil. The data were obtained from the Brazilian Registry System of Storage Units for the 2014/2015 season. The association between variables under study was carried out with the chi-square test of independence and correspondence analysis. The cluster analysis consisted of the unweighted pair group method with arithmetic mean and considered a measure of mixed dissimilarity obtained for sets composed of qualitative and quantitative variables. A significant association was observed between the type of silo battery with the grain usage characteristic and cooperatives that commercialize the grain for use in the domestic market (CICOOPT); between the bulk warehouse and cooperatives that commercialize the grain in the foreign market (CIECOOPT); and between the silo and grain sellers who commercialize the grain in the domestic market (CI). Most types of storage units were grouped in Group 1, with a predominance of the CI characteristic and small to medium size static and dynamic capacity.

INTRODUCTION

Agricultural storage capacities are related to the usage characteristics of the grain that can be commercialized in domestic and foreign markets. Storage units such as silo battery, bulk, and silo are more complex in terms of their storage system, as they are built with innovative techniques that allow a better quality in the conservation of the stored grains. Intended to store exclusively soybean, corn, and wheat for consumption in domestic and foreign markets, they have their typology, which ranges from individual to large structures, with sophisticated technologies to ensure agility in the transfer and security of the goods. Conventional warehouses are more used for storing grains commercialized in the domestic market, such as rice, cotton, bean, peanuts, soybean, corn, wheat, sorghum, among others (CONAB, 2017).

The lack of strategies and investments in agricultural storage capacity in Brazil can compromise Brazilian agribusiness, which is one of the main world producers of food (Trindade & Pacheco, 2015). Despite the great advances in Brazilian and Paraná agribusiness, there is a permanent grain storage deficit, estimated at approximately 69 and 7 million tons, respectively (Cicolin & Oliveira, 2016; Coelho & Maistro, 2017; CONAB, 2019).

Understanding the different types and capacities of storage infrastructure available, associated with the grain usage characteristics, is relevant for the production of safe and quality food (Patino et al., 2013). In practical terms considering soybean, corn, and wheat, it allows subsidizing business strategies for cooperatives and grain sellers by allowing a broader view of the sizing of storage units and promoting better quality management in grain storage that must meet biosecurity standards (Vieira & Dalchiavom, 2018).

Overall, grains are stored in Brazil in upright concrete silos, metal silos, and bulk warehouses. However, there are constructive differences between these storage units. Silo batteries are usually of metallic structure, of flat plates, galvanized iron, or aluminum, manufactured in series and built under a concrete floor.

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Area Editor: Edilson Costa
Received in: 11-26-2018
Accepted in: 4-9-2020

Metal silos can be built at a high level or ground level, being used by processing agro-industries and trading companies (grain importer and exporter). Conventional warehouses are built in the horizontal format and can be precast, with grains stored in bags under pallets. Bulk warehouses are built horizontally, being widely used to store soybean, corn, and wheat.

Structural warehouses are considered subtypes of conventional warehouses, being used by farmers with low purchasing power, as these structures are built on a clay base and products are stored bagged. Deposits are constructions designed for other purposes and transformed by adaptations into emergency storage units for the short term (CONAB, 2015).

Therefore, statistical techniques such as the chi-square test of independence (χ^2) and the multivariate analysis can be applied to study the association between the types of storage units and grain usage characteristics by the consumer market (Jansa et al., 2014) and understand the existing relationships between variables (Monteiro et al., 2017).

Correspondence analysis is an exploratory analysis technique used to study the associations between two or more categorical variables, allowing the visualization of the relationships between rows and columns in the same graphical space (Gouvêa et al., 2013; Petrukhin, 2017). Cluster analysis is widely used and has the principle of bringing together individuals that have similarities to each other, allowing for a better analysis of the data and pointing out behavior patterns (Barros et al., 2016; Dunmore et al., 2018). Also, cluster analysis can be used individually or associated with other techniques (Dhanachandra & Chanu, 2017).

In this sense, this study aimed to identify whether there is an association between types of storage and categories of commercialization and use of grains, group the types of storage with the categories of commercialization, and group the static and dynamic capacities of the units in the state of Paraná, Brazil.

MATERIAL AND METHODS

Study area and databases

The study area comprised all the 399 municipalities of the state of Paraná, located in the South region of Brazil (Figure 1), where 2985 grain storage units (SUs) are located. The georeferenced database of SUs was obtained from the Brazilian Registry System of Storage Units (SICARM) of the National Food Supply Company (CONAB, 2015) and consists of the following data: warehouse code, storer, address, municipality, state, type of warehouse, warehouse characterization, telephone, e-mail, total static capacity, and geographic coordinates (latitude and longitude) of the SUs for the 2014/2015 season.

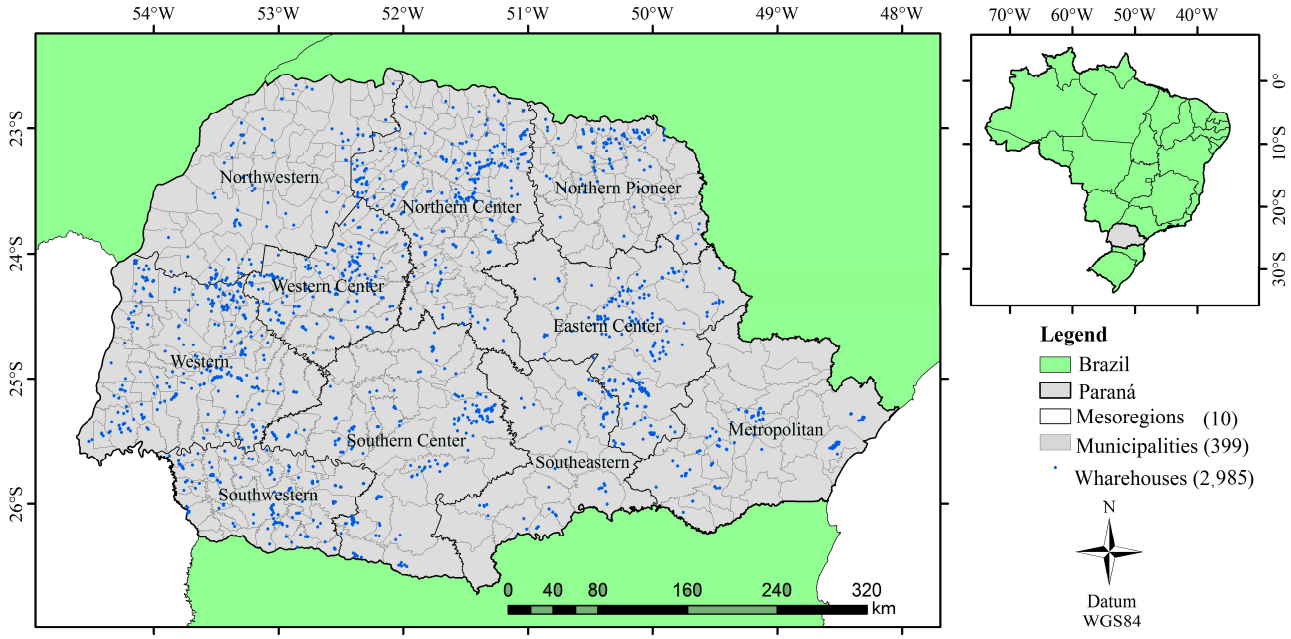

FIGURE 1. Map with the location of the grain storage units in the state of Paraná, Brazil.

The data warehouse characterization allowed identifying the typology of registered warehouses (TW), which were identified as silo battery (Silo.B), conventional warehouse (Conv), bulk warehouse (Bulk), metal silo (Silo), and others (conical, structural, and deposit warehouses). The latter type (others) is less frequent in the state of Paraná.

The SUs were organized into four categories (CI, CIE, CICOOPT, and CIECOOPT) regarding the commercialization, use, and export of grains (CUE). CI storage units are composed of cereal sellers, traders, and rural producers who store and commercialize grains (soybean, corn, and wheat) only in the domestic market.

Storage units categorized as CIE included cereal sellers and traders that sell grains in the domestic and foreign markets. SUs classified as CICOOPT referred to cooperatives and agro-industries that commercialize or transform grains (into vegetable oil and bran) only for consumption in the domestic market. Finally, SUs categorized as CIECOOPT represent cooperatives and agro-industries that commercialize or transform grains in the domestic and foreign markets. The attributes of grain quality were considered in each typology and category.

The total dynamic storage capacity (DSC) was calculated from the data of total static storage capacity (SSC) of the 2985 SUs, considering a grain turnover index of 1.5 (Coelho & Maistro, 2017).

Data analysis

The types of SUs were used in the study of the correspondence analysis. The chi-square statistical test of independence (χ^2) was applied at a 5% significance level, followed by the correspondence analysis, to analyze the existence or not of association between the types of SUs and categories regarding the use of grains.

In addition, after identifying the significant association between variables, the Student t-test of comparison of means was applied at a 5% significance level between the types of SUs for each fixed grain usage characteristic and the grain usage characteristics for each type of fixed storage unit to check whether there is a difference or similarity between the mean of types of SUs and CUE.

Five typologies (TW) of SUs (silo battery, conventional warehouse, bulk warehouse, metal silo, and others), four categories (CUE) regarding the use of grains (CI, CIE, CICOOPT, and CIECOOPT), SSC, and DSC were considered in the cluster analysis of SUs.

Qualitative variables (TW and CUE) were transformed into nine binary variables, considering the absence and presence of storage units, as suggested by Bilbas et al. (2017).

The data of the quantitative variables (SSC and DSC) were standardized, which consisted of transforming each variable into a standard score (Z score), thus eliminating the bias resulting from different scales of the variables. In summary, standardization by the Z score method consists of making each variable (Z) to present a mean equal to zero and variance equal to one. Moreover, dissimilarity was standardized (variables were structured on the same scale), in which a mixed dissimilarity measure was obtained and a dissimilarity matrix was constructed (Bilbas et al., 2017).

The tree clustering was used by the unweighted pair group method with arithmetic mean was used, allowing the construction of taxonomies of various levels, that is, a hierarchical agglomerative clustering method in which the dendrogram distances are preserved and resulting from the clustering of original distances.

The cophenetic correlation coefficient (CCC) was used to define the number of k clusters, that is, to make sure that the clusters differ from each other. According to Silva & Dias (2013), a CCC higher than 0.7 means a better-quality clustering.

The frequency and proportion of SUs concerning the total of each cluster were calculated after the clusters were formed, being classified according to the type of storage unit (TW) and categories of grain usage (CUE) for the 2014/2015 season in the state of Paraná. All data analyses were performed using the software R Studio version 3.3.5 (R Development Core Team, 2018). The construction of maps of SUs in terms of typology (TW) and categories of grain usage (CUE) was performed using software ArcGIS version 10.3. The elaboration of cluster maps considered the clustering of each typology in relation to each grain usage category.

RESULTS AND DISCUSSION

The chi-square test of independence (χ^2), performed at a 5% significance level, indicated the existence of a significant association between the types of SUs (silo battery, conventional warehouse, bulk warehouse, metal silo, and others) and their categories (CUE) of grain usage (CI, CIE, CICOOPT, and CIECOOPT). The correspondence analysis was performed between these variables to better detail this association (Figure 2).

The variables CI, CICOOPT, CIECOOPT, silo battery, bulk warehouse, and metal silo were close to each other relative to the first axis (Dim1), with a 77.14% contribution in the relationship between all categories. The variables CIE and others are distant from the other categories, especially regarding the second axis (Dim 2), which is responsible for explaining 21.24% of the relationship between all categories. The proximity of points on the correspondence graph (Figure 2) indicated that the types of SUs that have the highest association with the grain usage categories are the silo battery and CICOOPT, bulk warehouse and CIECOOPT, and metal silo and CI.

Seventy cooperatives in Paraná commercialize grains in the domestic (CICOOPT) and foreign markets (CIECOOPT), which receive, process, and consume large quantities of grains (mainly corn and soybean) daily to supply their agro-industrial systems.

In this context, the correspondence analysis was relevant for understanding the behavior and dynamics of the types of agricultural storage, as the demand for grain from cooperatives and agro-industries is frequent. This relevance is consistent with storage demands, as typologies and categories that showed an association are related to the need to use the grain.

The multivariate analysis using the correspondence analysis method, which considered the association between typology and categories of SUs, showed that the grain storage systems are indispensable in agribusiness due to their responsibility of receiving, conserving, and distributing the available supply of grain production on the consumer market.

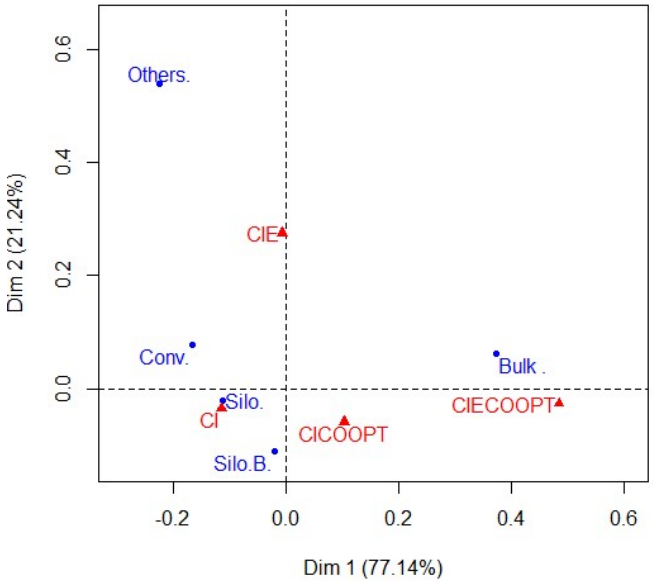

FIGURE 2. Correspondence analysis of the typology (TW) Silo.B (silo battery), Conv (conventional warehouse), Bulk (bulk warehouse), Silo (metal silo), and others (conical, deposit, and structural warehouses) and categories of grain storage units (CUE) (CI: cereal sellers and farmers who sell grains in the domestic market; CIE: cereal sellers and traders that sell grains in the domestic and foreign markets; CICOOPT: cooperatives that receive, transform, and commercialize grains for consumption in the domestic market; CIECOOPT: cooperatives that receive, transform, and commercialize grains for consumption in the domestic and foreign markets).

The means of static storage capacity (SSC) (Table 1) of the types of storage units (silo battery, conventional warehouse, bulk warehouse, metal silo, and others) in relation to the grain usage characteristics (CI, CIE, CICOOPT, and CIECOOPT) showed similarities and significant differences between TW for each type of CUE and vice versa by the Student t-test of multiple comparisons of means at a 5% significance level.

The categories of TW showed that SUs of the types silo battery type and bulk warehouse had SSC statistically equal only for companies of the type CIE and CIECOOPT. The conventional warehouse differed statistically only for CIE, with the highest SSC among all other categories. All SSC values for metal silos were statistically equal to each other, while the category others showed a significant difference between CI and CIE (Table 1).

The analysis of SSC for each CUE relative to the type of warehouses (TW) shows that companies with CI characteristics had the types silo battery and others, as well as conventional warehouses and others, statistically equal to each other, with the lowest SSC and differing significantly from bulk warehouses (the highest SSC value). CIE companies showed that the categories silo battery and others, as well as bulk warehouse and others, were statistically equal to each other, with the highest SSC, but the conventional warehouse and metal silo were equal to each other, but with the lowest SSC. All TW in the grain usage characteristic of CICOOPT showed significant differences for SSC. Also, only the types of conventional warehouse and metal silo (lowest SSC) were statistically equal to each other for CIECOOPT (Table 1).

TABLE 1. Means (thousand tons) of the static storage capacity (SSC) of the types of storage units (TW) and grain use characteristics (CUE).

CUE/TW	Silo battery	Conventional warehouse	Bulk warehouse	Metal silo	Others
CI	8,060	3,243	13,222	3,344	6,083
CIE	20,451	5,668	32,147	3,488	37,756
CICOOPT	13,998	2,813	21,004	4,338	--
CIECOOPT	20,500	3,580	28,443	4,941	--

According to the Student t-test for comparison of means (Table 1), the storage of the type of silo battery and conventional warehouse, as well as bulk warehouse and silo, is related to SUs of medium to high static (SSC) and dynamic storage capacity (DSC), common for trading companies and cooperatives that commercialize grains in the domestic and foreign markets (CI, CIE, CICOOPT, and CIECOOPT).

The western Paraná is home to the five largest cooperatives in Brazil, namely Coopavel, Lar, Coopacol, Coopervale, and Coopagril (CICOOPT and CIECOOPT) (OCEPAR, 2015), which store grains in silos and in their agro-industrial systems, standing out emphasis on poultry, pig, dairy, and fish farming (Voges et al., 2016).

Significant differences were observed for CIE and conventional warehouse and CICOOPT in all types of SUs. This difference shows that the categories CIE and CICOOPT varied according to the types of SUs arranged in the different regions in the state of Paraná. This difference may be related to the different dynamics of

commercialization and use of grain that occur in the different categories (trading and cooperatives) and typology of storage.

The best clustering of data of the storage units occurred with the formation of five clusters, as it resulted in the highest CCC (0.874).

According to Silva & Dias (2013), a CCC higher than 0.70 means an excellent adjustment between the graphic representation of the distances and its original matrix, which immediately shows high reliability in making inferences when using the unweighted pair group method with arithmetic mean.

This result corroborates what Cima et al. (2018) found when studying the univariate autocorrelation and the bivariate spatial correlation of total grain production (soybean, first- and second-crop corn, and wheat) with SSC and the total amount of warehouse in the 2013/2014 season in the state of Paraná. The results of the five groups are shown in Table 2 in terms of quantity and proportion of SUs.

TABLE 2. Quantity and proportion of storage units in relation to the total of each group, classified according to the type of storage unit (TW) and categories of grain usage (CUE) for the 2014/2015 season in the state of Paraná, Brazil.

Type of storage unit (TW)		Category of grain usage (CUE)				
		CI	CIE	CICOOPT	CIECOOPT	Total
Group 1 (G1)	Silo battery	754 (25.9%)	95 (3.3%)	142 (4.9%)	131 (4.5%)	**1122(38.5%)**
	Conventional	669 (22.9%)	147 (5.0%)	118 (4.0%)	67 (2.3%)	**1001(34.3%)**
	Bulk warehouse	251 (8.6%)	72 (2.5%)	89 (3.1%)	125 (4.3%)	**538 (18.4%)**
	Metal silo	153 (5.3%)	25 (0.9%)	28 (1.0%)	20 (0.7%)	**226 (7.8%)**
	Others	19 (0.7%)	9 (0.3%)	-	2 (0.1%)	**30 (1.0%)**
	Total	**1846(63.3%)**	**348 (11.9%)**	**377 (12.9%)**	**346 (11.9%)**	**2917(100%)**
Group 2 (G2)	Silo battery	-	-	-	-	**0 (0%)**
	Conventional	-	-	-	-	**0 (0.0%)**
	Bulk warehouse	31 (62.0%)	8 (16.0%)	-	10 (20.0%)	**49 (98.0%)**
	Metal Silo	-	1 (2.0%)	-	-	**1 (2.0%)**
	Others	-	-	-	-	**0 (0.0%)**
	Total	**31 (62.0%)**	**9 (18.0%)**	**0 (0.0%)**	**10 (20.0%)**	**50 (100%)**
Group 3 (G3)	Silo battery	2 (14.3%)	-	6 (42.9%)	6 (42.9%)	**14 (100%)**
	Conventional	-	-	-	-	**0 (0.0%)**
	Bulk warehouse	-	-	-	-	**0 (0.0%)**
	Metal silo	-	-	-	-	**0 (0.0%)**
	Others	-	-	-	-	**0 (0.0%)**
	Total	**2 (14.3%)**	**0 (0.0%)**	**6 (42.9%)**	**6 (42.9%)**	**14 (100%)**
Group 4 (G4)	Silo battery	-	1 (50.0%)	-	-	**1 (50%)**
	Conventional	-	-	-	-	**0 (0.0%)**
	Bulk warehouse	-	-	-	1 (50.0%)	**1 (50%)**
	Metal silo	-	-	-	-	**0 (0.0%)**
	Others	-	-	-	-	**0 (0.0%)**
	Total	**0 (0.0%)**	**1 (50.0%)**	**0 (0.0%)**	**1 (50.0%)**	**2 (100%)**
Group 5 (G5)	Silo battery	-	-	-	-	**0 (0.0%)**
	Conventional	-	-	-	-	**0 (0.0%)**
	Bulk warehouse	-	2 (100%)	-	-	**2 (100%)**
	Metal silo	-	-	-	-	**0 (0.0%)**
	Others	-	-	-	-	**0 (0.0%)**
	Total	**0 (0.0%)**	**2 (100%)**	**0 (0.0%)**	**0 (0.0%)**	**2 (100%)**

CI: cereal sellers and farmers who sell grains in the domestic market; CIE: cereal sellers and traders that sell grains in the domestic and foreign markets; CICOOPT: cooperatives that receive, transform, and commercialize grains for consumption in the domestic market; CIECOOPT: cooperatives that receive, transform, and commercialize grains for consumption in the domestic and foreign markets.

Group 1 (G1) had 97.7% (2917 out of the 2985 SUs) of the SUs in the state of Paraná, Brazil, located in the mesoregions Pioneer North, Northwest, North Central, Eastern Central, West, Southwest, Metropolitan, South Central, and Western Central (Figure 3).

The largest numbers were found in the mesoregions North Central in the municipality of Apucarana (51 SUs), Eastern Central in the municipality of Castro (27 SUs), Western Central in the municipality of Campo Mourão (63 SUs), South Central in the municipality of Guarapuava (98 SUs), and West in the municipality of Cascavel (106 SUs).

In group 1 (G1), there are 25.9% of the SUs of the type silo battery and 22.9% of the conventional warehouse, followed by 8.6% of the bulk warehouse, 5.3% of the

metal silo, and 0.7% of the other types of warehouses (conical, structural, and deposit warehouses) (Table 2).

Storage units with the lowest SSC and DSC of grains (Table 3), with a predominance of the category CI (Table 2), which demonstrates that most cereal sellers and farmers store their grains for the domestic market. SUs and SSC in this cluster varied between 91 and 70,080 thousand tons, with a mean of 8,402 thousand tons and a standard deviation of 10,736 thousand tons (Table 3).

TABLE 3. Descriptive statistics of the total static (SSC) and dynamic storage capacity (DSC) (thousand tons) for the 2014/2015 season in the state of Paraná, Brazil, according to the clusters.

Groups	Capacity	Minimum	Mean	Maximum	Standard deviation	CV(%)
Group 1	SSC	91	8,402	70,080	10,736	128
(n = 2917)	DSC	137	12,604	105,120	16,104	
Group 2	SSC	32,830	71,256	126,290	23,592	33
(n = 50)	DSC	49,245	106,884	189,435	35,389	
Group 3	SSC	46,960	74,827	106,990	19,415	25
(n = 14)	DSC	68,940	112,240	160,485	29,122	
Group 4	SSC	252,100	258,950	265,800	9,687	4
(n = 2)	DSC	378,150	388,425	398,700	14,531	
Group 5	SSC	164,293	182,074	199,854	25,145	14
(n = 2)	DSC	246,440	273,111	299,781	37,717	

n: number of warehouses; CV: coefficient of variation; SSC: total static storage capacity; DSC: dynamic storage capacity.

The West of Paraná was grouped in G1 because it is a large grain (soybean and corn) producer, where SSC and DSC varied from small to medium capacity. This result suggests that the high grain supply is not compatible with SSC and DSC in the region. The lack of warehouses near the grain-producing regions and poor storage structures in terms of physical space and aeration of the environment can cause losses in the post-harvest.

Another 50 SUs were grouped in Group 2 (G2), which corresponds to 1.70% of the total SUs in Paraná. A predominance of the bulk warehouse was observed (49 out of 50 SUs) (Table 2), with an SSC variation between 32,830 and 126,290 thousand tons and mean storage of 71,256 thousand tons and 33% variability (Table 3). These SUs are mostly in the category CI (31 SUs), followed by CIECOOPT (10 SUs), and CIE (8 SUs), in addition to one metal silo in the category CIE.

The main differences in Group 2 relative to Group 1, besides the group size, is the increase in static and dynamic storage capacity (Table 3).

No biased behavior (distributed at random in the regions of the state of Paraná) was observed regarding the location of SUs in G2 (Figure 3), thus reflecting the same pattern of location of SUs in the state. These storage units are located in the mesoregions Metropolitan, Eastern Central, North Central, and West, standing out the municipalities of Maringá (2 SUs), Ponta Grossa (9 SUs), Cascavel (6 SUs), and Paranaguá (4 SUs).

Groups 3 to 5 (G3, G4, and G5) showed only 18 SUs (Table 2), with a predominance of G3 in the type of silo battery (12 SUs) in the categories CICOOPT and CIECOOPT (Table 2) for grain use. SUs in G3 are located mainly in the municipalities of Ponta Grossa (2 SUs) and Guarapuava (3 SUs) (Figure 3).

Group 4 (G4) and 5 (G5) had only 2 SUs each, composed of silo battery and CIE, bulk warehouse with CIECOOPT (G4), and bulk warehouse with CIE (G5) (Table 2). The mean SSC of G3 was 74,827 thousand tons (Table 3), which is similar to that found for G2 (mean of 71,256 thousand tons). The largest SUs, on the other hand, were grouped in G5 (mean of 182,074 thousand tons) and G4, with 258,950 thousand tons (Table 3), and are located in the South Central (Guarapuava and Nova Laranjeira) and Eastern Central (Ponta Grossa).

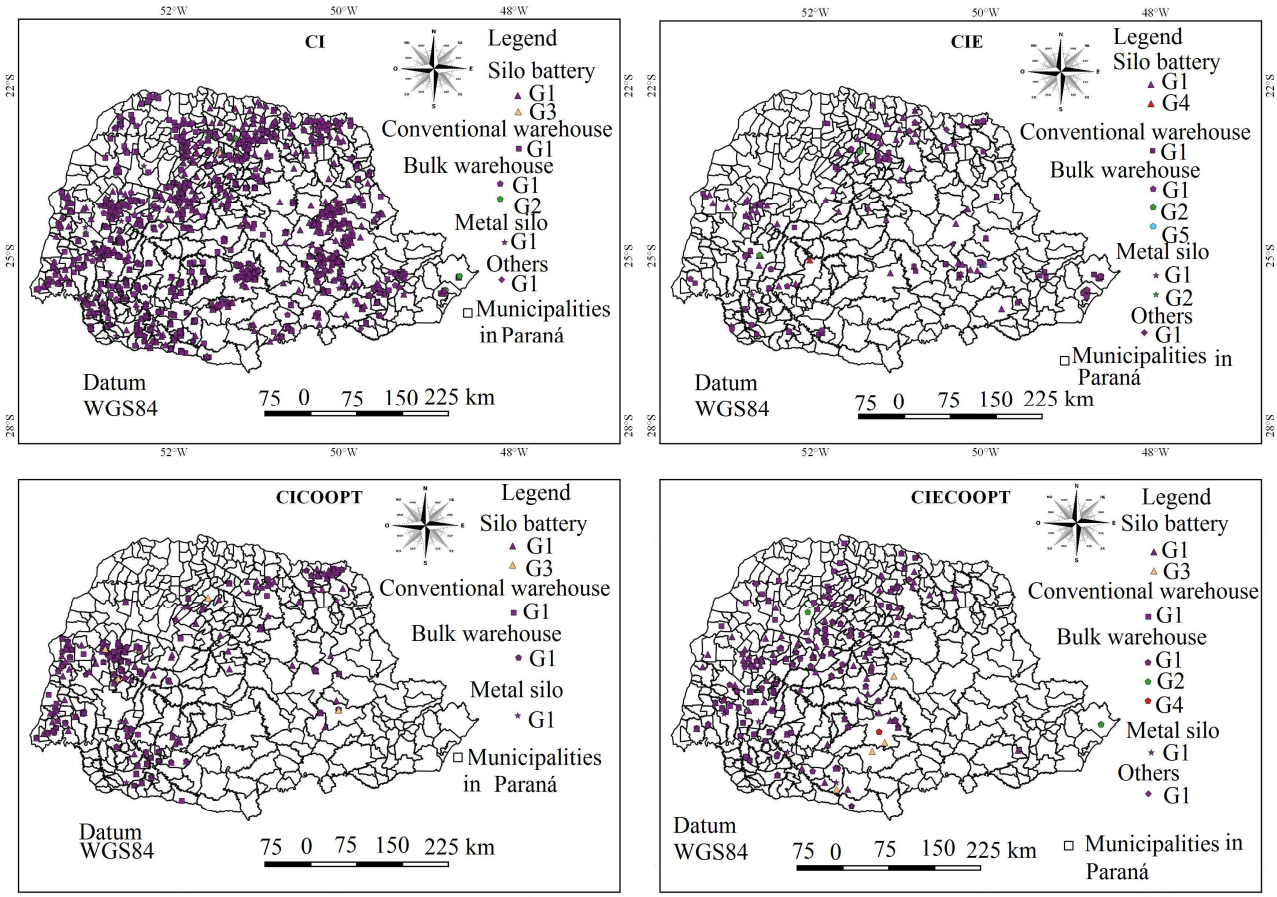

FIGURE 3. Location of clusters. G1: Group 1; G2: Group 2; G3: Group 3; G4: Group 4; G5: Group 5.
The SUs of G5 were superimposed over the other storage units (Figure 3) due to the proximity between them.

This high static capacity for grain storage in these regions is justified by the presence of agro-industrial grain cooperatives (CICOOPT and CIECOOPT), grain sellers, and traders (CIE) that store and commercialize the grains the domestic and foreign markets. The cooperative Agrária Agroindustrial, the trading company Louís Dreyfus Company Brasil S.A, Bunge Alimentos, and the seller Iriedi Ltda (CONAB, 2015) stand out in these three municipalities.

Silo batteries (15 out of 18 SUs in G3 to G5), even though with different ways of commercializing grains, are the predominant type of storage structure for high SSC and DSC.

This result was already expected, given that trading companies and cooperatives (CIE and CIECOOPT) invest a lot in this type of storage system.

These groups have cereal sellers (CI) such as Granosul Agroindustrial, Plantar, Canal Cooperativa de Sementes Agroindustrial, and Cooperativa Agroindustrial de Sementes Nova Produtiva (CONAB, 2015). The commercialization characteristics CIECOOPT and CIE are related to cooperatives such as Coamo, Cocamar, Coopavel, the BRF Foods group, and trading companies such as Bunge, Cargill, Monsanto, Belagricola, among others (CONAB, 2019).

The characteristics of receiving, transforming, and commercializing grains (CICOOPT and CIECOOPT) are present in agro-industrial cooperatives. Silo batteries are medium to large structures that allow the domestic supply necessary to meet the demand for grains that cooperatives need. Many of them consume practically all the stored grains, mainly soybean and corn, for the manufacture of feed and supply of agro-industrial systems for feeding broilers and pigs, while the surplus grain is exported especially to Asia by companies such as Coamo, Cocamar, and BRF Foods. The main cooperatives (Coopacol, Coopagril, C-Vale, and Coasul) are located mainly in the West, Southeast, and Pioneer North regions of the state of Paraná.

The results obtained by the cluster analysis showed what Rosa et al. (2017) and Vianna et al. (2013) detected, that is, that the application of the multivariate analysis using the unweighted pair group method with arithmetic mean is interesting in the analytical process of grain storage data. A high frequency of similar groups with SUs (silo batteries, conventional warehouse, and bulk warehouse) was observed (Table 2).

The cluster multivariate method showed that SSC varied in the 399 municipalities of Paraná, with significant differences in SSC and DSC, randomly distributed in the different municipalities, thus demonstrating the high variation between the physical space (capacity in tons) from one structure to another.

The study showed a high-frequency association between the types of SUs and the grain usage characteristic, that is, the high similarity of these variables, which allowed a high connection between them and the similarity of different types of SUs in the same group and their characteristics between different groups.

In this sense, the cluster analysis was efficient in this study, which focused on static and dynamic storage capacities, types of grain storage units, and grain usage

characteristics in the state of Paraná in the 2014/2015 season. Overall, the cluster analysis allowed a wide view of how the dynamics of the types of storage units, capacities, and grain usage characteristics in the state of Paraná behave.

CONCLUSIONS

A significant association was observed in the 399 municipalities of the state of Paraná, Brazil, between the types of storage units: silo batteries and CICOOPT, bulk warehouse and CIECOOPT, and metal silo and CI.

The test of comparison of means showed similarities between the types of silo batteries, conventional warehouse, bulk warehouse, and metal silo with the grain usage characteristics, CI, CIE, CICOOPT, and CIECOOPT.

The cluster analysis showed that the highest number of storage typologies were grouped in Group 1, with the characteristic CI appearing more frequently, which shows SSC and DSC from small to medium sizes.

Higher-capacity SSC and DSC were grouped in Groups 2, 3, 4, and 5, with relevance to the categories CIE and CIECOOPT.

ACKNOWLEDGMENTS

This research was carried out with the support of the Coordination for the Improvement of Higher Education Personnel (CAPES) (grant number 001), National Council for Scientific and Technological Development (CNPq), Araucária Foundation, PGEAGRI and Laboratory of Spatial Statistics-LEE, of the State University of Western Paraná-Brazil-UNIOESTE.

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