Available online at www.centmapress.org

INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Proceedings in
System Dynamics and Innovation in Food Networks 2023

DOI: http://dx.doi.org/10.18461/pfsd.2023.2307

Cluster Analysis Of Soybean Farms Participating In The Agro Plus Program In The State Of Minas Gerais, Brazil[1]

Antônio Consentino Teixeira Oliveira[a], Aziz Galvão da Silva Júnior[a], Zhang Min[b]

[a] *Department of Rural Economics, Federal University of Viçosa, Brazil.* antonio.consentino@ufv.br; aziz@ufv.br
[b] *College of Agriculture, Nanjing Agricultural University, China.* springzm@njau.edu.cn

Abstract

Brazil is the world largest producer and exporter of soy and sustainability is a key issue for Brazilian import markets. In this context, the Agro Plus program, former Soja Plus, was set up in the early 2010s by the Brazilian Vegetable Oil Industries and Farmers Associations (ABIOVE) with the objective of improving the environmental and social conditions of the agricultural production. The Agro Plus has been implemented in 5.300 farms nationwide using a checklist which comprises around 230 indicators divided into Social-Environmental and Rural Construction major themes. In Minas Gerais State the program is coordinate by the Federal University of Viçosa (UFV) and the Farmers´ Association. Based on the updated version of the checklist applied in 123 farms during the 2021/22 season in Minas Gerais, the objective of the paper was to identify critical indicators and groups of farms, allowing the discussion and proposition of individual and collective actions. By the cluster analysis, three groups of farms (A, B and C) were identified comprising of 18, 77 and 22 farms respectively. Identified critical indicators and the analysis of farms´ groups allowed the proposition of focused capacity building to specific group of farms. The expansion of the analysis, including data from other Brazilian states, will allow a more robust evaluation of the program and comparisons between the different regions. Furthermore, it would be very opportune to include data from other states and discuss the results considering the requirements of specific markets, such as China.

Keywords: sustainability; soybean chain sustainability; Brazilian soybean.

1. Introduction

In the last four harvests, Brazil has surpassed the United States as the world's largest producer of soy. The competitiveness of Brazilian soy production is the result of favorable edaphoclimatic conditions, availability and implementation of producing technologies and an efficient chain coordination. However, the import markets impose increasing demands regarding social and environmental issues. In the soy complex (soybeans and processed products), the issue of sustainability is a growing concern of buyers, not only from the European Union, but also from the Brazilian largest trading partner, China

1 The paper is based on anonymous data provided by the agreement between Brazilian Vegetable Oil Industries Association (ABIOVE) and The Federal University of Viçosa (UFV).

(ABIOVE, 2023; FEFAC, 2021; Silva Júnior, 2016; WWF, 2015; Visser, 2014; Brown-Lima, 2010; MAPA, 2021).

China is the world's largest soybean importer. In 2020, the world's soybean imports reached 167 million tons. China's imports were 103 million tons, equivalent to 62% of world export market. In 2019, China imported 58 million tons of soybeans from Brazil, and Brazil became China's largest source of soybean imports. Imported soybeans will help alleviate the shortage of agricultural resources in China and promote China's food security development. As a leader in world trade, China should take a more active role and participate in the initiative to promote the sustainable production of Brazilian soybeans (Min, 2022).

For the soy chain, the International Trade Center (ITC) Standard Map lists 93 certification systems related to the sustainability of this commodity (ITC, 2023). Certification systems are important instruments, but by definition they require compliance with all mandatory requirements, including the labor and environmental requirements of producing countries. But in the other hand, certification is a process that inevitably excludes producers who do not meet the minimum requirements. Furthermore, most certification does not consider the specific edaphoclimatic conditions and the availability of natural, human and financial resources of the rural properties.

In this context, the Soja Plus Program was created in 2011 by the Brazilian Association of Vegetable Oil Industries (ABIOVE) in partnership with the Soy and Corn Producers Association of Mato Grosso State (APROSOJA-MT). In 2022, the program was extended to others production chains and named as Agro Plus. The Agro Plus objective is to improve the management of rural properties, considering the conditions of each producer. The program is a nationwide, transparent and participatory initiative, aiming at meeting market demands for sustainable products. The program is based on gradual and continuous improvement of the environmental, social and economic aspects of production through evaluation of more than 230 indicators.

The thematic lines of action of the Agro Plus program includes:

- Quality of life at work;
- Best production practices;
- Economic viability;
- Product quality;
- Social responsibility and;
- Rural constructions.

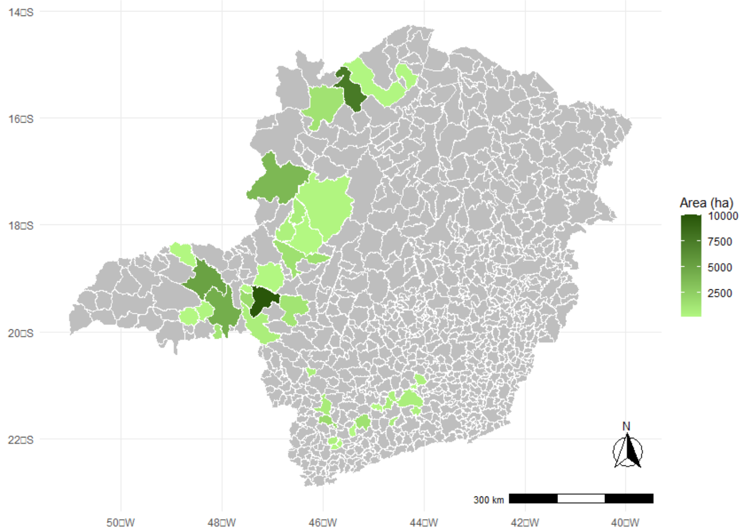
2. Objectives

The general objective of the paper is to contribute to the improvement of the Agro Plus Program in the state of Minas Gerais, through the identification of groups of farms and critical indicators for the implementation of individual and collective actions. Specifically, the objectives are:

- Carry out descriptive statistical analysis and cluster analysis of the results of the Agro Plus indicators;
- Discuss and compare the results considering different regions in the Minas Gerais and propose individual and collective actions.

3. Methodology

Data were obtained through the application of the Agro Plus program in 123 soy farms in the state of Minas Gerais in 2021. The map below represents the sum of soybean areas of theses farms by municipality.



Source: authors

Fig. 1 – Sum of soybean production area of Agro Plu's farms by municipalities in Minas Gerais State.

Mean and standard deviation of themes. Initially, univariate analyses were performed to evaluate each checklist theme individually. Mean and standard deviation were measured for each theme, allowing an initial perspective of the farm's situation in the Minas Gerais State. The maps of results by municipalities were built using the R programming language version 4.1.0.

Cluster Analysis is a multivariate statistical technique that groups objects based on their similarities (Rossoni et al., 2021). Thus, groups are created with objects similar to each other and different from the objects of the other groups (Rodrigues, Fachel, Passuelo, 2012), in such a way that the analysis by group facilitates the understanding of the database and to direct decision making of the studied problem. A hierarchical grouping methodology was used, which, according to Rohlf (1970), forms several homogeneous groups that gradually gather in larger and more heterogeneous groups.To group objects based on their similarity, it is necessary to measure the similarity or dissimilarity between them. The measure adopted was the Euclidean distance, which consists of an extrapolation of the Pythagorean theorem, given by:

$$D_{x,y} = \sqrt{\Sigma_k{}^n},$$

where T_{kx} is the percentage reached in theme K by farm X and T_{ky} is the percentage reached in the same theme K by farm Y.

Then, the farms were grouped by the linkage criteria (single, complete, average, centroid and minimum variance) whose dendrogram resulted in the highest cophenetic correlation with the dissimilarity matrix. Finally, ANOVA was carried out to verify the difference of the averages of each cluster. As the Agro Plus database is extensive, this analysis is useful to facilitate the assessment of farms by groups, allowing them to be categorized and identify the most critical issues in certain groups. This helps to optimize the assistance provided by the program and its customization.

4. Results and Discussion

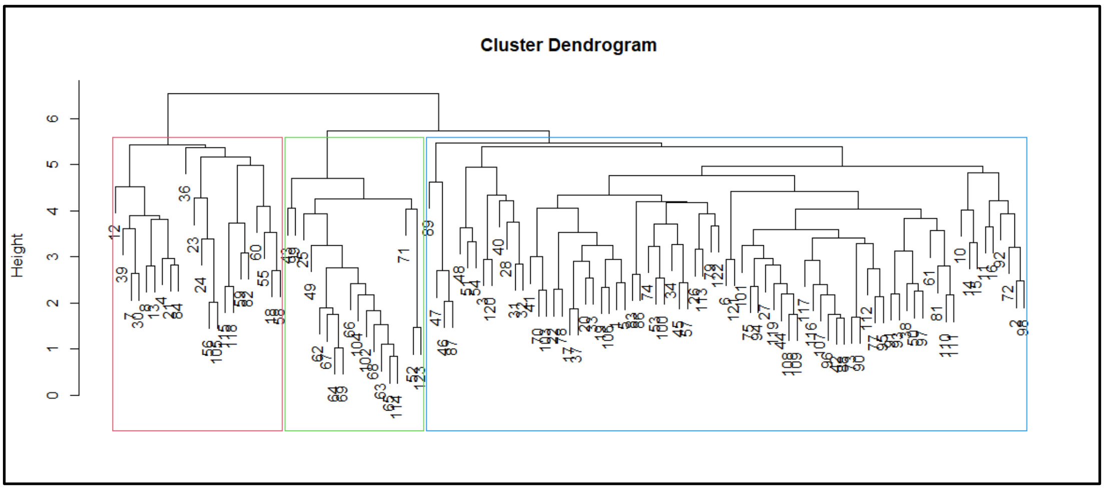
Univariate analysis

Among the 123 farms visited, in which the updated checklist was applied, the worst results of the Socio-Environmental major themes were indicators related to: i) *Risk Management in the Work Environment* (T5); ii) *Training and Capacity Building* (T6) and; iii) *Waste Management and Good Practices* (T7). The risk management (T5) theme in the update version of the checklist has more indicators than previous years, which currently better detail the actions of the owners to minimize the risks associated with the functions of the employees. It can be noted that it is one of the topics that most deserves Agro Plus focus to guide and training participants, especially considering the low standard deviation and consequent uniformity between farms. *Training and Capacity Building* (T6) is a topic of the updated version of the checklist, which includes some indicators that were in other topics before, such as pesticides, risk management and accident prevention.

The averages related to the indicators of the *Rural Constructions* major theme were lower than those of the *Socio-Environmental* theme. The *Agrochemical Packaging Storage* (T14) and *PPE Laundry* (T19) indicators obtained the lowest averages and demonstrate that they have great potential for improvement in the soybean farm in Minas Gerais state. The indicator *Silos and Dryers (*T15), which was recently added to the checklist, also stood out negatively. Some properties do not yet have these constructions, for this reason the dissemination of information and training are important for new constructions to reach the appropriate standard.

Table 1 – Mean and standard deviation (%).

Social and Environmental themes	Mean	Standard Deviation
Agrochemicals T1	86.99	8.37
Work Contract T2	78.47	17.40
Health and Safety Management T3	78.32	19.18
Work Environment T4	69.76	18.45



Risk Management in the Workplace T5	54.03	21.11
Training and Capacity Building T6	45.99	30.13
Waste Management and Good Practices T7	61.87	14.73
Environmental Regularization T8	80.41	16.23
Financial Control T9	87.61	19.68
Rural Constructions themes		
Accommodation for Employees T10	69.24	30.55
Housing for Employees T11	94.75	12.15
Living Area T12	71.94	38.06
Agrochemical Deposit T13	62.88	27.33
Agrochemical Packaging Deposit T14	43.02	34.88
Silos and Dryers T15	57.32	37.38
Fuel Filling Point T16	65.97	24.22
Maintenance, Washing and Oil Change Area T17	62.53	32.02
Machinery Shed T18	61.39	24.02
PPE Laundry T19	17.66	32.95

Source: authors.

Cluster Analysis

Six (6) farms with discrepant observations were eliminated, leaving 117 for cluster analysis. Also, it excluded the specific themes T10, T15 and T17 due they are not available in more than 40 % of the partners farms. The average linkage criteria had the highest cophenetic correlation, however it was 0.618. This reveals a not very good fit of the method in relation to the dissimilarity calculated by the Euclidean distance. With a greater number of farms. the clustering would have better preserved the dissimilarity and the correlation would have been greater. In any case, it is relevant to analyze and interpret the groups, since the cophenetic correlation is not so low and the averages of the themes are significantly different between the groups.

Source: authors.

Fig. 2 – Cluster dendrogram.

The best number of groups to be interpreted. based on the dendrogram was three. The group vwas named group A, B and C, encompassing 18, 77 and 22 farms respectively.

Table 2 - Mean (%) by themes.

Groups	T1	T2	T3	T4	T5	T6	T7	T8	T9	T11	T12	T13	T14	T16	T18	T19
A	97	90	97	83	83	87	66	91	93	98	97	93	88	82	84	69
B	85	80	77	71	53	42	64	83	88	96	74	66	43	67	62	10
C	84	58	62	53	30	21	50	65	77	91	34	30	12	50	32	1
p-value*	<0,05															

*ANOVA showed a significant difference between groups for all themes at 5% probability.

Source: authors

Table 3 - Standard deviation (%) by theme.

Groups	T1	T2	T3	T4	T5	T6	T7	T8	T9	T11	T12	T13	T14	T16	T18	T19
A	4,8	9,7	5,8	18,0	17,0	12,9	14,5	8,4	13,5	4,1	7,9	7,4	25,7	23,3	11,8	35,0
B	7,7	15,3	15,9	13,6	13,9	23,9	13,4	12,3	19,2	6,6	35,0	21,0	30,0	20,9	20,7	25,7
C	6,5	15,6	23,1	19,8	12,8	25,7	11,2	15,8	22,9	8,4	40,6	23,8	17,4	27,6	18,0	4,7

Source: authors

Group A had the best averages for all themes. It contains the farms with the highest compliance with the indicators. Only the theme T19 (IPE laundry) was under 70%, meaning that improvements are necessary in some farms of group A.

Most of the farms assisted by the new checklist are at an intermediate management level, constituting group B. They have high averages in the best-scored themes throughout the state, but very low in T5, T6, T14 and T19. The focus of actions should focus on risk management, employee training, waste management and adapting the Agrochemical Packaging Storage (T14) and IPE laundry (T19) facilities.

Finally, group C is made up of properties that are less covered by the legislation and that need to improve in many aspects. Even so, it is worth highlighting positively T1, T9 and T11, whose averages are very high in these 22 farms, which shows the potential they have in adapting the other indicators. With managerial assistance and guidance, the producer is able to bring his property fully into compliance.

With the results of this analysis, it can be said that most farms have ample scope to improve their sustainability, especially focusing on the aforementioned points. To optimize and customize the assistance provided by the Agro Plus program, it is important to train: 1) all properties in terms of Waste Management and Good Practices (T7) and IPE Laundry; (T19) 2) those belonging to groups B and C regarding risk management, employee training and packaging deposit and; 3) those in group C, specifically regarding the work environment, living area, agrochemical deposit and machine shed.

5. Conclusions

The results of the analyzes using the selected methodologies allowed discussing and proposing measures to increase the efficiency of the Agro Plus program. The identification of indicators with lower averages in each municipality will make it possible to direct the elaboration of didactic material and the intensification of training for different regions and, using the results of the cluster analysis, for groups of farms with similar characteristics. The expansion of the analysis, including data from other Brazilian states, will allow a more robust evaluation of the program and comparisons between the different regions. Furthermore, it would be very opportune to include data from other states and discuss the results considering the requirements of specific markets, such as China.

Acknowledgments

To ABIOVE for coordinating the Agro Plus program at the national level and for the opportunity to contribute to it through scientific statistical results. Also, to CNPq, the main Brazilian research promotion agency, for granting a scholarship for this study.

References

ABIOVE (2023). Associação Brasileira das Indústrias de Óleos Vegetais. Estatísticas. Available at: <http://abiove.org.br/sobre/> (accessed 04.01.1023).

Brown-Lima, C., Cooney, M., Cleary. (2010). An overview of the Brazil-China soybean trade and its strategic implications for conservation. The Nature Conservancy: Arlington. Available at: <https://www.readkong.com/page/an-overview-of-the-brazil-china-soy> (accessed 01.10. 1023).

FEFAC (2021). European Compound Feed Manufacturers' Federation. Soy Sourcing Guidelines 2021. Available at: <fefac.eu/wp-content/uploads/2021/02/FEFAC-Soy> (accessed 01.10.2022).

Hotelling, H. (1933). Analysis of a complex of statistical variables into principal components. Journal of Educational Psychology. vol. 24. n. 6. p. 417-441.

IBGE (2022). Available at:<www.ibge.gov.br> (accessed 01.10.2023).

Jolliffe, I. T. (1973). Discarding variables in a principal component analysis. II: Real data. Applied Statistics. v. 22. n.1. p. 21-31.

MAPA (2021). Com foco na sustentabilidade. Brasil e China discutem ações para a agricultura em diálogo bilateral. Available at: <https://www.gov.br/agricultura/pt-br/assuntos/noticias/coml> (accessed 04.10.2022).

MIDIC (2023). Available at: <http://comexstat.mdic.gov.br/pt/home> (accessed 01.10.2023).

Min, Z., Silva Junior. A. G., Suya, Y., Aijun. L. (2022). Analysis on the sustainable production of soybean in Brazil. Research in Food Issues. 29.

Rodrigues, A., Fachel, J. M. G., Passuelo, A. C. (2009). Estatística espacial e análise de cluster em dados de desastres naturais: mapeamento das inundações no Rio Grande do Sul entre 2003 e 2009. Revista Iniciação Científica 10(1): 48-67.

Rohlf, F. J. (1970). Adaptive hierarchical clustering schemes. Systematic Zoology.

Rossoni, R. A., Moraes, M. L., Catellan, R. (2021). O Perfil da Modernização da Agricultura do Paraná: Uma análise de Cluster. IGepec. Toledo. Edição Especial: 58º Congresso da SOBER, 25: 29-45.

Silva Júnior. A. G., Zanasi, C., Souza Jr., W., Ajona, J. V. G. (2016). Matching Brazilian soybean production to the EU sustainability standards' requirements. Compliance of the SojaPlus management program with the FEFAC guidelines. 10th EAAE-IGLS Forum. Innsbruck-Austria.

Visser, C. L. M., Schreuder, R., Stoddard, F. (2014). The EU's dependency on soya bean import for the animal feed industry and potential for EU produced alternatives. Oilseed and Fat Crops and Seeds. 21(4) D407.

WWF (2015): Solving the soy problem. Available at: <http://wwf.panda.org/what_we_do/footprint/agriculture/soy/> (accessed 01.10.2023).