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Analysis of the Agroecological Behavior of Family Farmers in Nova Friburgo (Brazil) and Mendoza (Argentina), Based on the Application of Fuzzy Logic

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Abstract. The analysis of agroecological behaviors, based on indicators using a mathematical system to support decision-making, is something very unusual in academia. Therefore, we propose the use of indicators that take into account the qualitative and quantitative nature. The hypothesis assumes that information expressed through natural language, proposed in fuzzy logic, can lead to a better adaptation of data processing from informants. The comparative perspective addresses the environment and human beings, with their customs and productions in Nova Friburgo (Brazil) and Mendoza (Argentina), and uses fuzzy methodology, in order to facilitate modeling and make the problem solution more viable and realistic for several complex problems, involving many variables. As a result, we have a model that can analyze and identify which factors (peasantry, sustainability, social organization and rural development agency) and respective indicators make the greatest contribution to the adoption of agroecological practices. Encouraging decision makers and policymakers to strategically reflect on scenarios, in the context of the agroecological transition, is fundamental and can be facilitated by implementing an innovative monitoring and evaluation approach.

1 Introduction

Humans assimilate and utilize data with fuzzy rules and imprecise information, precisely what enables them to make decisions regarding situations governed by randomness. The human brain reasons in an environment where facts are only partially known, basing its decisions on vague, ambiguous, or incomplete information. In this sense,

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to represent the uncertainties of everyday life, fuzzy sets were conceived as a mathematical reasoning based on a generalization of conventional set theory [1].

Fuzzy logic was introduced into scientific circles in 1965 by Lotfi Asker Zadeh with the publication of the article "Fuzzy Sets and Systems" in the journal "Information and Control" [2]. Today, it is a fundamental element in various mathematical systems, considered an excellent technique in the computational universe. It also has enormous acceptance in the field of process control.

The basic operations in fuzzy sets are a generalization of those used in Boolean sets (union, intersection, complement, etc.), presenting, however, more diversified applications, as they allow the definition of linguistic terms and variables capable of representing different levels and thresholds of manifestation of a characteristic associated with an attribute, a component of a criterial group, through the association of the linguistic variable with a fuzzy number, which in turn expresses membership functions, allowing for valued transitions between different linguistic terms of a variable in the representation of an attribute.

Thus, when characterizing the membership of an element in a set, unlike in Crisp Logic where binary values are associated: belongs or does not belong, contains or does not contain, true or false, processing by fuzzy logic provides us with information on how much it belongs, how much it contains, how true it is. In this way, levels of manifestations are related by thresholds and gradual transitions between the association of an element with a set, associated with terms representing linguistic variables cognitively linked to the perception of greater or lesser value.

Additionally, in an extension of the tools derived from Euclidean mathematics, fuzzy logic establishes a more comprehensive universe of tool options for data processing, expanding the possibilities for algorithm modeling, improving information capture, and addressing the need to work with complexity and subjectivity from the perspective of accepting the presence of uncertainties, inaccuracies, and vagueness in sources of information. It is a case of recognizing the limits of mathematics and data computing and an opportunity to explore information processing, accepting the existence of natural imprecision common to human thought, nature, and the complexity of the assessment and prediction environments, as a way to provide results more adherent to reality.

Thus, the use of indicators that take into account the qualitative-quantitative nature of information and are expressed through natural language can lead to better adequacy from the perspective of the quality of data treatment derived from informants. In this study, the methodology based on fuzzy logic is used to evaluate the predictability of agroecological behavior based on its levels of development in different groups of indicators. Understanding the profile of the family farmer and their behaviors, as well as their specificities, can contribute decisively to the development of sustainable productive activity, with the generation of employment and income.

The premise of this work is that the traditional evaluation methods currently used carry a very high degree of uncertainty and subjectivity, with several independent variables difficult to measure. Therefore, the classification of agroecological behavior and its evaluation becomes a very complex and subjective task given the various variables involved and their nature. This article seeks to present a methodology based on fuzzy logic for evaluating the prediction of agroecological behavior and suggest its application as a tool for identifying determining characteristics of family farmers to evolve in agroecological transition.

To do so, the agroecological behavior of family farmers in Nova Friburgo (Brazil) and Mendoza (Argentina) is evaluated using Fuzzy Logic, starting with the specification of fuzzy methodology. In the following sections, evaluations of agroecological behavior based on Fuzzy Logic are presented, distinguishing family farmers from Nova Friburgo and

Mendoza, with the proposal of models and characterization maps of agroecological transition indices. It ends with some final considerations.

2. Materials and Methods

The target audience in both researched regions consisted of family production systems engaged in the cultivation of vegetables and flowers, for conducting interviews with a representative from each farming family visited at their workplace.

In Nova Friburgo (Brazil), initially, a list obtained from the local office of the Rural Technical Assistance and Extension Company of the State of Rio de Janeiro (EMATER-RIO) was considered, consisting of farmers eligible to access credits from the National Program for Family Agriculture Support (PRONAF), totaling 1567 with a PRONAF Eligibility Declaration (DAP). From this database, a stratified random sample of 3% [3] was conducted, resulting in the selection, through a lottery, of 47 interviewed vegetable and flower producers.

In Mendoza (Argentina), the sampling methodology was adjusted to match the work demands with the availability of time and resources. Thus, it was previously characterized, through conversations with key local actors, that the study region had about 600 family farmers producing vegetables and flowers, with the majority located in the municipalities of Guaymallén, Maipú, and Lavalle (vegetables), and Las Heras (flowers).

In Argentina, a stratified random sample of 3% [3] was also used, establishing the sample size at 18 interviewees, with five from Guaymallén, three from Maipú, seven from Lavalle, and three from Las Heras. However, for selecting the interviewees, the choice was random but not by lottery. In the case of vegetable producers, a car journey was undertaken along a road traversing the three mentioned municipalities, and whenever a farmer was sighted, the vehicle would stop, and the farmer would be asked if they agreed to participate in the interview. If the response was affirmative, the questionnaire was administered; if negative, the journey continued. Additionally, respecting the established quantity for each municipality, interviews were conducted with farmers participating in agroecology and bioinput production workshops held in Lavalle. For flower producers in Las Heras, interviews were conducted at a flower marketing space in the capital of the province of Mendoza.

The study of the agroecological profile is not only relevant as a theoretical contribution to the subject but also because it helps to better understand how agroecological behavior can assist conscious social actors in making sustainable practices choices, contributing to the agroecological transition process. Thus, based on the analysis of the interviews, it was possible to characterize sets of agroecological behaviors.

The approach proposed by the fuzzy aggregation model had practical value, making it possible to include the expertise of specialists (knowledge-driven) in defining the weights for indicator sets that describe levels of peasant identity, sustainability, social organization, and rural development agency (research, technical assistance and rural extension, and technical guidance), among other aspects.

The characteristics of the agroecological profile were structured into four sets of evaluation indicators: the peasant identity set, sustainability set, social organization set, and rural development agency set. And, the indicators for evaluating each of them were:

- Peasant identity set (Table 1): expresses the importance of peasant ethics values that have a production organization based on family labor and its use as a value, which may present a greater or lesser degree of peasant identity according to its life trajectory and its integration into modern capitalist society [4];
- Sustainability set (Table 2): the continuous pursuit of new balance points between different dimensions which, at a first level, we consider to be ecological, economic, and social, which may be conflicting in concrete realities [5]. They

involve agricultural practices that conserve or improve the chemical, physical, and biological conditions of the soil and maintain or improve agrobiodiversity and water resource quality; agricultural practices that improve the quality of life of farmers and consumers by eliminating the use of toxic and transgenic inputs and by reducing the hardship and facilitating work; agricultural practices with low consumption of non-renewable energies that promote income generation with less dependence on external inputs;

- Social organization set (Table 3): networks of social organization and representations of the various segments of the rural population, which encourage harmonious interaction between humans, the agroecosystem, and the environment [6];
- Rural development agency set (Table 4): facilitators in the field (research, technical assistance and rural extension, and technical guidance) that seek to articulate social and environmental dimensions, in a collective effort aimed at building strategies and projects for sustainable rural development, culturally acceptable and capable of maintaining and stabilizing the social fabric formed from family production units, while seeking to reduce environmental impacts on agroecosystems, produce healthy food, and ensure the generation of employment and income in rural areas [7].

Table 1 - Peasant Identity Set.

Indicator	**Strategies used for differentiation between modes of production**
Energy	Reduced dependence on external inputs and increased efficiency through organic matter management and nutrient cycling strategies, biological nitrogen fixation, use of own seeds, and rational use of irrigation water
Scale	Reduced agricultural land size
Self-sufficiency in external inputs	Provision of ecosystem services
Workforce	Provision of workforce primarily sourced from the family
Multifunctionality of labor	Application of agricultural activities (soil preparation, planting, and commercialization) and non-agricultural activities, as well as subsistence production.
Ecological productivity	Environment, with its natural diversity and enrichment.
Agrobiodiversity	Diversity of cultivated species and varieties.
Knowledge	Traditional knowledge, non-modern.
Cosmovision	Harmony of knowledge.

Table 2. Sustainability Set

Indicator	Agricultural practices used for analyzing sustainability in ecological, social, and economic dimensions include:
Weed management	Especially mowing, weeding, and incorporation of weeds.
Soil preparation strategies	Especially minimum tillage, mechanical soil preparation (plowing, harrowing, ridging, and leveling), mechanical soil preparation in fishbone pattern, associated with soil cover.
Green manure	Especially when not desiccating (without herbicide use), does not incorporate crop residues.
Liming and fertilization	Especially organic fertilization, liming, chemical fertilization with insoluble fertilizers, soil analysis, composting.
Phytosanitary management	Especially when not using any products, alternative pest and disease control, application of biofertilizer.
Seeds	Especially when using own seeds of local varieties and commercial varieties.
Irrigation	Especially conventional with low-pressure and localized spraying (micro-sprinkler, drip irrigation).
Cultivation system	Crop rotation, intercropping, agroforestry system, herbicide-free no-tillage, integration of plant and animal production activities.

Table 3. Social organization set.

Indicator	Means used to strengthen the social organization of family farmers:
Participation	Conscious and active involvement in activities of common interest.
Representativenes s	Encouragement of diversity, based on the plurality of social actors.
Representation	Task distribution, delegating power: the president represents the organization in social and political events. Specific and permanent committees are created to address issues, with members representing them.
Planning and management	Committees plan actions and projects based on diagnoses and executive plans, with annual and multi-year frequency, along with monitoring and evaluation of results.
Transparency	The organization's mission, copies of minutes, and other documents such as financial reports are displayed on a panel available to all. The minutes are prepared by the members, and other documents are archived in individually named folders and digitized.
Decision-making	Decision-making preferably involves dialogical and democratic processes, aiming for consensus to give voice to everyone.

Participants' willingness	Participants gather in a circle, where no one occupies a prominent position. Thus, everyone teaches and learns, reflecting the uniqueness of knowledge.
Relevant topics	Prioritized topics are discussed in meetings and worked on by permanent committees.
Training	Thematic workshops are organized for continuous education, as well as lectures and training sessions, including during regular meetings, as requested by participants.
Succession	The board members are renewed through general elections.
Empowerment	Representatives, in a process of empowerment, occupy decision-making spaces such as associations, municipal councils in the agricultural sector, other councils, watershed committees, regional associations, and forums.

Table 4. Rural development agency set.

Indicator	**Actions used required from DRS agents (research, ATER and technical guidance)**
Collective action on a productive unit	Collective action on property or production unit (participatory knowledge construction, technical meeting, demonstration of methods, field day, etc.)
Collective action in social organization	Collective action in association, union, cooperative, and other organizations (meeting, lecture, etc.)
Individual action on a productive unit	Individual action on property or production unit (participatory research, observation unit, etc.)
Individual action on a rural establishment	Individual action through technical guidance in store or office (recommendation, exchange of experience, clarification, etc.)
Unavailable educational action	Educational action not provided or receives occasional information from various sources.

2.1. Evaluation of the agroecological behavior of family farmers in Nova Friburgo (Brazil) and Mendoza (Argentina)

Numeric terms, linguistic terms, and rubrics were used, as can be observed in the example of Table 5, where linguistic terms, defined as a fuzzy subset $\mu:(x)\ \xi\ [0,1]$, are assigned degrees of membership.

Table 5 - Examples of numerical term, linguistic term, and rubric used for the attribute Agrobiodiversity, referring to the set/factor of peasant identity, obtained from the social tool "Differentiation between modes of production in family farming".

Numerical term	**1 (minimal level)**	**2; 3; and 4 (intermediate levels)**	**5 (extreme level)**
Linguistic term	Very low agrobiodiversity	Intermediate agrobiodiversity	Very high agrobiodiversity

Rubric	Agricultural system with very low species diversity, using hybrid and transgenic genetic materials. Use of conventional practices in simplified management systems (monoculture).	Agricultural systems with low, medium, and high species diversity	Agricultural system with very high diversity of species, varieties, and breeds. Use of agroecological practices in complex management systems.

The numerical terms were used according to the Likert scale, to identify the five stages of gradation, associated with linguistic terms and rubrics to support the extremes, through four sets or factors (peasant identity, sustainability, social organization, and rural development agency), with nine, eight, eleven, and five attributes and five numerical terms, presented in Table 6.

Table 6 - Sets/factors, number of attributes, and numerical terms.

Sets/Factors	Nº	Attributes	Likert Values
Peasant identity	9	Energy, Scale, Self-sufficiency of External Inputs, Workforce, Work Multifunctionality, Ecological Productivity, Agrobiodiversity, Knowledge, Worldview	1, 2, 3, 4, 5
Sustainability	8	Weed Management, Soil Management and Preparation Strategies, Green Manure, Liming and Fertilization, Phytosanitary Management, Seeds and Seedlings, Irrigation, Cultivation System	
Social Organization	11	Participation, Representativeness, Representation, Planning and Management, Transparency, Decision-making, Distribution of Participants, Relevant Themes, Training, Succession, Empowerment	
Rural Agency	5	Collective Action on a Productive Unit, Collective Action in Social Organization, Individual Action on a Productive Unit, Individual Action in a Rural Establishment, Unavailable Educational Action	

There are several types of measurement scales focused on human behavior, and the Likert scale is one of the most commonly used. There are two basic types, unipolar and bipolar. We selected the bipolar scale, which is based on the presence of two diametrically opposed entities (two poles) and intermediate options in terms of response choices, to facilitate understanding of the issue and consequently the respondent's choice of the best option.

The Likert scale can be used, for example, to measure the level of satisfaction, degree of importance, frequency of occurrence, degree of difficulty, and level of disagreement. We opted for the frequency of occurrence, expressed in quantity, with (1) very low, (2) low, (3) medium, (4) high, and (5) very high.

Thus, information was collected using the Likert scale supported by rubric technique that declares the boundaries of the evaluation. Then, the numerical data from 1 to 5 was associated with fuzzy sets for data processing, fuzzy analysis, and model evaluation, as shown in Fig.1.

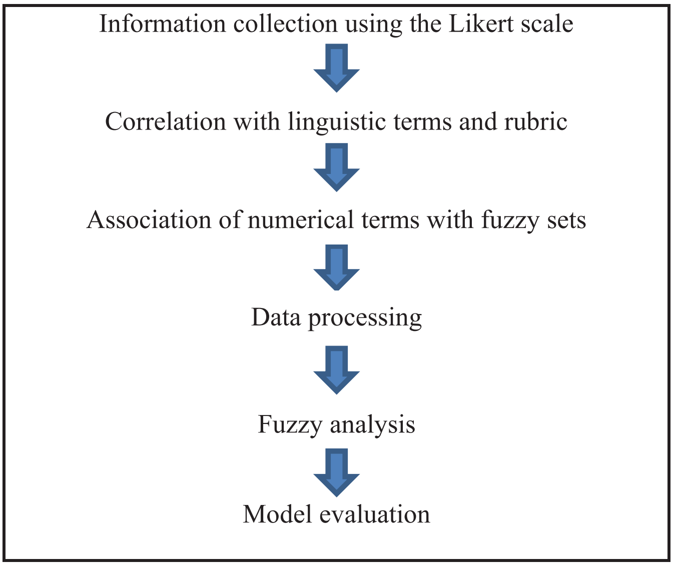

Fig. 1. Methodological steps based on Fuzzy Logic used. Source: The authors.

The method allowed the construction, through fuzzy logic, of mathematical models obtained from complex systems. Thus, it was possible to describe mathematically using functions, matrices, and graphically (Equations 1, 2, 3, 4, and 5; Matrix 1; Figure 2).

$$\begin{aligned}&Fuzzy\ Set\ 1 = if\ 0 \le x \le 0{,}1\ \ then\ \mu(x) = 1\\ &else\ if\ 0{,}1 \le\ x \le 0{,}3\ then\ \mu(x) =\ -5x + 1{,}5\end{aligned} \tag{1}$$

$$\begin{aligned}&Fuzzy\ Set\ 2 = if\ 0{,}1 \le x \le 0{,}3\ \ then\ \mu(x) = 5x - 0{,}5\\ &else\ if\ 0{,}3 \le\ x \le 0{,}5\ \ então\ \mu(x) =\ -5x + 2{,}5\end{aligned} \tag{2}$$

$$\begin{aligned}&Fuzzy\ Set\ 3 = if\ 0{,}3 \le x \le 0{,}5\ \ then\ \mu(x) = 5x - 1{,}5\\ &else\ if\ 0{,}5 \le\ x \le 0{,}7\ \ then\ \mu(x) =\ -5x + 3{,}5\end{aligned} \tag{3}$$

$$\begin{aligned}&Fuzzy\ Set\ 4 = if\ 0{,}5 \le x \le 0{,}7\ \ then\ \mu(x) = 5x - 2{,}5\\ &else\ if\ 0{,}7 \le\ x \le 0{,}9\ \ then\ \mu(x) =\ -5x + 4{,}5\end{aligned} \tag{4}$$

$$\begin{aligned}&Fuzzy\ Set\ 5 = \{if\ 0{,}7 \le x \le 0{,}9\ \ then\ \mu(x) = 5x - 3{,}5\\ &else\ if\ 0{,}9 \le\ x \le 1\ \ then\ \mu(x) =\ 1\end{aligned} \tag{5}$$

Fuzzy set matrix describing the attributes used:

$$\begin{bmatrix} 0 & 0 & 0{,}1 & 0{,}3 \\ 0{,}1 & 0{,}3 & 0{,}3 & 0{,}5 \\ 0{,}3 & 0{,}5 & 0{,}5 & 0{,}7 \\ 0{,}5 & 0{,}7 & 0{,}7 & 0{,}9 \\ 0{,}7 & 0{,}9 & 1 & 1 \end{bmatrix}$$

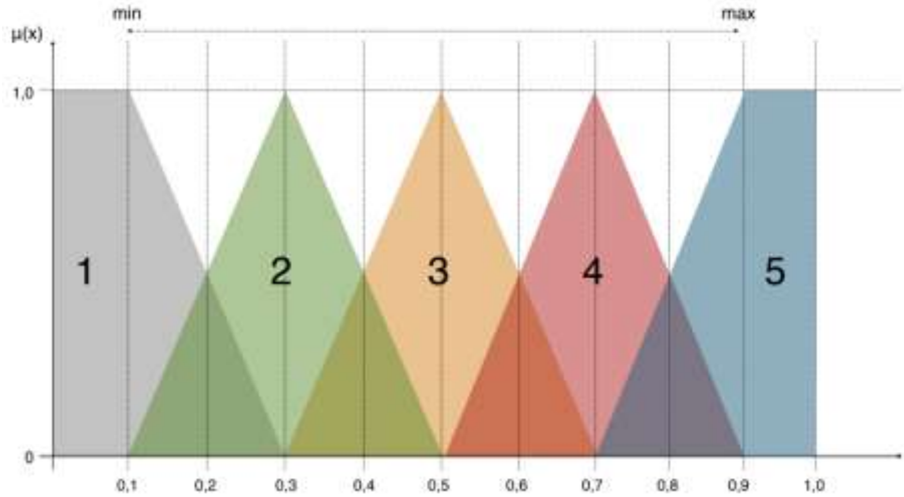

Fig. 2. Graphical representation of the Fuzzy sets for describing the attributes that converted the Likert scale to Fuzzy numbers.

Given the structuring of Factors, Attributes, and Indicators, calculations were applied to the indices. Then, the data collected on the Likert scale were converted to the fuzzy scale, transforming the numbers from 1 to 5 into fuzzy sets. Figure 3 illustrates the sequence of logical reasoning or steps applied in the algorithm used.

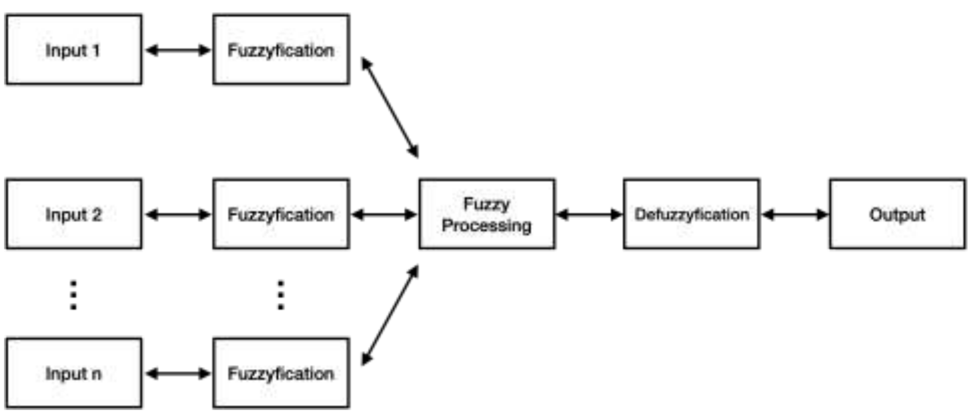

Figure 3. Logical reasoning or steps applied in the algorithm used for processing.

From this point on, fuzzy arithmetic was applied by summing up the component attributes of each group of factors, in this case, four factors, and dividing them by the number of attributes describing the present factors. In this way, a fuzzy set was obtained that aggregates the scores obtained in the evaluated attributes for each agricultural production unit (UPA), which were divided by the number of attributes, in order to obtain a resulting set of the adherence of the UPA to agroecology, measured in the degree of membership by its membership indicator, and in the pattern represented as an extreme set of maximum and minimum possible results.

An extreme maximum set is considered to be a UPA that has maximum performance in all attributes (resulting score in five in everything), and similarly, an extreme minimum set is a UPA that has minimum performance in all attributes (resulting score one in everything).

Function that expresses the maximum and minimum extremes of sets:

$$F_i = \frac{\sum_{j=1}^{n} \mu_{ij}}{n} \tag{6}$$

Observing that the evaluation of the Factors is composed of attributes with different levels of importance, different levels of weight (w_{ij}) were assigned to the component attributes of each factor in the construction of the index, through consultation with specialists, as shown in Table 7.

Table 7 - Factors, with respective attributes and weights.

Factors	**Attributes**	**Weights**
Peasant identity	Energy	1
	Scale	0,5
	Self-sufficiency of External Inputs	0,8
	Workforce	0,8
	Multifunctionality of Work	0,9
	Ecological Productivity	0,7
	Agrobiodiversity	0,8
	Knowledge	0,9
	Worldview	0,6
Sustainability	Control of Spontaneous Plants	1
	Soil Management and Preparation Strategies	1
	Green Manure	1
	Liming and Fertilization	1
	Phytosanitary Management	1
	Seeds and Seedlings	1
	Irrigation	1
	Cultivation System	1
Social Organization	Participation	1
	Representativeness	0,9
	Representation	0,6
	Planning and Management	0,8
	Transparency	0,9
	Decision Making	0,8
	Participant Distribution	0,5
	Relevant Topics	0,8
	Training	0,8
	Succession	0,7
	Empowerment	0,7
Rural Agency	Collective Action in Production Units	1
	Collective Action in Social Organization	0,7
	Individual Action in Production Units	0,6
	Individual Action in Rural Establishment	0,4
	Unavailable Educational Action	0,1

Thus, from the application of the weights (w_{ij}), expressed in pertinence, equation 6 was rewritten, forming equation 7:

$$F_i = \frac{\sum_{j=1}^{n} w_{ij} * \mu_{ij}}{\sum_{j=1}^{n} w_{ij}} \quad (7)$$

The equation 7 was applied in methods presented by Narasimhan [8] and Baas; Kwakernaak [9]. The centroid defuzzification method was used to convert the vector referring to the resulting fuzzy number, and as a way to simplify it into a comparable reference index [10], in which the maximum value of the triangles and trapezoids resulting from the calculation process is calculated. Thus, Figure 2 presents the space delimited by the maximum values of the fuzzy numbers used as input, forming a delimited space between 0.1 and 0.9 of pertinence. The final result presented in this work applied adjustment methods, scaling final results to values between 0 and 1, by calculating the index obtained in defuzzification, subtracted from the minimum possible value obtained, divided by the maximum possible value obtained, subtracted from the minimum possible value obtained. This means that the result, originally obtained from the figures, is again presented on a scale with values varying from "zero" to "one".

3 Results and Discussion

Analyzing the resulting sets, some interesting characteristics are observed, which are due to a greater convergence or dispersion of the results, measured through the distance from the base of the resulting set, revealing greater or lesser homogeneity in meeting the attributes of the factor.

This measure reflects the effective performance in the evolution of the UPA in meeting the attributes, revealing that, on average, the result has greater representativeness when the UPA has a smaller distance from the base of the resulting fuzzy number, indicating a greater concentration of individual attribute results at a trend point. Similarly, the distance from the base of the resulting fuzzy number shows us whether the UPA meets the component attributes of the factor, with individual results of these attributes represented with greater dispersion.

Thus, an equal pertinence value in fuzzy numbers with different bases revealed that UPAs with smaller bases demonstrate greater adherence to the factors representing the agroecological maturity result, while UPAs in which the resulting fuzzy numbers have larger bases meet the attributes at different levels. Thus, after the fuzzy analysis of the four factors, it was possible to obtain values for the factors of peasantness, sustainability, social organization, and rural development agency, referring to family production systems in Nova Friburgo and Mendoza, presented respectively in Tables 1 and 2. In this study, the most relevant information was collected to evaluate the premise that the adoption of socio-agrobiodiversity practices, such as those based on agroecology, is greater the closer the farming family comes to the peasant way of life, based on sustainability, and occurs with the improvement of social organization and support from sustainable rural development agents. This was confirmed by finding that family 43 from Nova Friburgo (Table 8) and family 10 from Mendoza (Table 9), which adopted a greater number of sustainable practices among the analyzed groups, were the ones that had higher indices of peasantness and social organization. However, even these better-evaluated families needed to increase their indices of rural development agency.

Table 8 - Values of the factors of Peasantness (F1), Sustainability (F2), Social Organization (F3), and Rural Agency (F4) of Nova Friburgo.

UNIDADE	F1	F2	F3	F4
Família 1	0,35	0,38	0,81	0,23
Família 2	0,54	0,56	0,63	0,06
Família 3	0,54	0,56	0,63	0,15
Família 4	0,47	0,47	0,61	0,28
Família 5	0,57	0,59	0,63	0,28
Família 6	0,54	0,56	0,63	0,28
Família 7	0,50	0,53	0,63	0,06
Família 8	0,50	0,53	0,67	0,00
Família 9	0,43	0,47	0,00	0,09
Família 10	0,48	0,50	0,80	0,15
Família 11	0,40	0,41	0,80	0,28
Família 12	0,66	0,69	0,80	0,28
Família 13	0,54	0,56	0,80	0,28
Família 14	0,57	0,59	0,76	0,28
Família 15	0,55	0,56	0,69	0,28
Família 16	0,63	0,66	0,76	0,28
Família 17	0,61	0,63	0,76	0,28
Família 18	0,54	0,59	0,76	0,28
Família 19	0,45	0,50	0,76	0,28
Família 20	0,46	0,50	0,76	0,68
Família 21	0,58	0,59	0,76	0,46
Família 22	0,45	0,53	0,86	0,06
Família 23	0,27	0,30	0,08	0,28
Família 24	0,57	0,59	0,78	0,46
Família 25	0,41	0,44	0,78	0,09
Família 26	0,64	0,66	0,86	0,68
Família 27	0,49	0,56	0,75	0,06
Família 28	0,47	0,53	0,76	0,06
Família 29	0,52	0,53	0,88	0,55
Família 30	0,54	0,53	0,88	0,28
Família 31	0,69	0,69	0,88	0,15
Família 32	0,50	0,50	0,72	0,28
Família 33	0,37	0,44	0,08	0,00
Família 34	0,52	0,53	0,80	0,28
Família 35	0,52	0,53	0,60	0,28
Família 36	0,54	0,56	0,08	0,00
Família 37	0,70	0,75	0,80	0,04
Família 38	0,72	0,72	0,89	0,04
Família 39	0,81	0,78	0,90	0,04
Família 40	0,45	0,47	0,70	0,23
Família 41	0,64	0,66	0,89	0,28
Família 42	0,64	0,66	0,89	0,28
Família 43	0,86	0,88	0,90	0,06
Família 44	0,49	0,56	0,08	0,00
Família 45	0,53	0,59	0,69	0,68
Família 46	0,46	0,53	0,08	0,00
Família 47	0,54	0,63	0,69	0,46

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Table 8 - Values of the factors of Peasantness (F1), Sustainability (F2), Social Organization (F3), and Rural Agency (F4) of Mendoza.

UNIDADE	F1	F2	F3	F4
Família 1	0,47	0,47	0,08	0,01
Família 2	0,40	0,41	0,08	0,01
Família 3	0,40	0,47	0,08	0,04
Família 4	0,57	0,53	0,86	0,09
Família 5	0,43	0,44	0,08	0,01
Família 6	0,38	0,44	0,81	0,41
Família 7	0,50	0,47	0,75	0,49
Família 8	0,54	0,53	0,75	0,49
Família 9	0,24	0,28	0,75	0,28
Família 10	0,72	0,69	0,86	0,41
Família 11	0,45	0,47	0,75	0,33
Família 12	0,44	0,44	0,08	0,04
Família 13	0,62	0,66	0,75	0,09
Família 14	0,52	0,56	0,08	0,00
Família 15	0,52	0,53	0,75	0,49
Família 16	0,37	0,41	0,81	0,41
Família 17	0,28	0,31	0,81	0,02
Família 18	0,32	0,28	0,67	0,00

3.1 Models of agroecological behavior

In assessing models of agroecological behavior of family farmers interviewed in Nova Friburgo and Mendoza, we selected the worst-rated or minimum agroecological behavior production system and the best-rated one. This allowed us to identify which attributes had the greatest scalar distance from the centroid. Thus, planning can aim to adjust priorities with the greatest differences, providing more significant gains.

In Nova Friburgo, the worst-rated production system was that of family 33 and the best-rated was that of family 43, resulting in the following observations:

- Regarding Factor 1 - Peasantness: there is a Euclidean distance of 0.49. To improve strategies related to the peasantness of family 33, actions involving the attributes Energy and Self-sufficiency of external inputs (more prioritized) are indicated.
- Regarding Factor 2 - Sustainability: there is a Euclidean distance of 0.44. To improve sustainability, actions involving the attributes Control of spontaneous plants and Green manure (more prioritized) are necessary.
- Regarding Factor 3 - Social Organization: there is a Euclidean distance of 0.82. To improve Factor 3, actions involving the attributes Participation, Representativeness, Transparency, Distribution of participants, and Relevant themes (more prioritized) are needed.
- Regarding Factor 4 - Rural Development Agency: the Euclidean distance is zero. However, it may still be considered moderately prioritized in the attribute Individual action in production unit and Individual action in rural establishment, due to the scalar distance. However, for effective improvement of this factor, Collective action in production unit and Collective action in social organization with family 33 are necessary. These actions occur (Factor 3) with family 43 (better rated), through the Participatory Guarantee System (SPG), contributing to Collective action in social organization (Table 8).

In Mendoza, the worst-rated production system was that of family 9 and the best-rated was that of family 10, with the following observations:

- Regarding Factor 1 - Peasantness: there is a Euclidean distance of 0.48. Thus, to improve the peasantness of family 9, it is necessary to develop actions involving the attributes Knowledge and Worldview (more prioritized).
- Regarding Factor 2 - Sustainability: there is a Euclidean distance of 0.44. To improve typical peasant behaviors of family 9, it is necessary to develop actions that improve the attributes Green manure and Cultivation system (more prioritized).
- Regarding Factor 3 - Social Organization: the Euclidean distance is small (0.11), with Empowerment being the only aspect still considered moderately relevant.
- Regarding Factor 4 - Rural Development Agency: the difference is also zero. However, due to the scalar distance, the attribute Individual action in production unit can be considered moderately prioritized. However, for effective improvement in this factor, Collective action in production unit and Collective action in social organization with family 9 are necessary. Family 10 is associated with the Movement of Excluded Workers (Factor 3), which contributes to Collective action in social organization (Table 9).

Table 10 Analysis of factors, according to the attributes to be prioritized, concerning the horticulturists of Nova Friburgo.

Factors	Attributes	
Factor 1: Peasanthood	Energy	Self-sufficiency of external inputs
Factor 2: Sustainability	Control of spontaneous plants	Green manuring
Factor 3: Social Organization	Participation, Representativeness, Transparency	Distribution of participants, Relevant themes
Factor 4*: Rural Development Agency	Individual action in production unit	Individual action in rural establishment

* For effective improvement of this factor, it is necessary to have collective action in the production unit and collective action in social organization with family 33. Source:

Table 11 – Analysis of factors, according to the attributes to be prioritized, concerning the horticulturists of Mendoza.

Factors	Attributes	
Factor 1: Peasanthood	Knowledge, Worldview	Self-sufficiency in external inputs, Agrobiodiversity, Ecological productivity
Factor 2: Sustainability	Green manure, Cultivation system	Irrigation and Weed control
Factor 3: Social Organization	Empowerment	-
Factor 4*: Rural Development Agency	Individual action in the production unit	-

*However, for effective improvement in this factor, it is necessary to have Collective action in the production unit and Collective action in social organization with family 9.

3.2 Maps depicting the characterization of agroecological transition indices.

The fuzzy logic-based model allows for analysis on larger scales (district, municipality, state) and smaller scales (small territory, production unit). It also enables greater flexibility in map combinations, using color gradation associated with Geographic Information Systems (GIS). Thus, maps of Nova Friburgo and Mendoza were produced, consolidating the four factors, making it possible to characterize the different fuzzy indices of agroecological transition in the analyzed family production systems. The more the color tends towards red, the production unit is more conventional, and the more the color tends towards green, the production unit is more agroecological, as can be seen in Fig. 4 and 5.

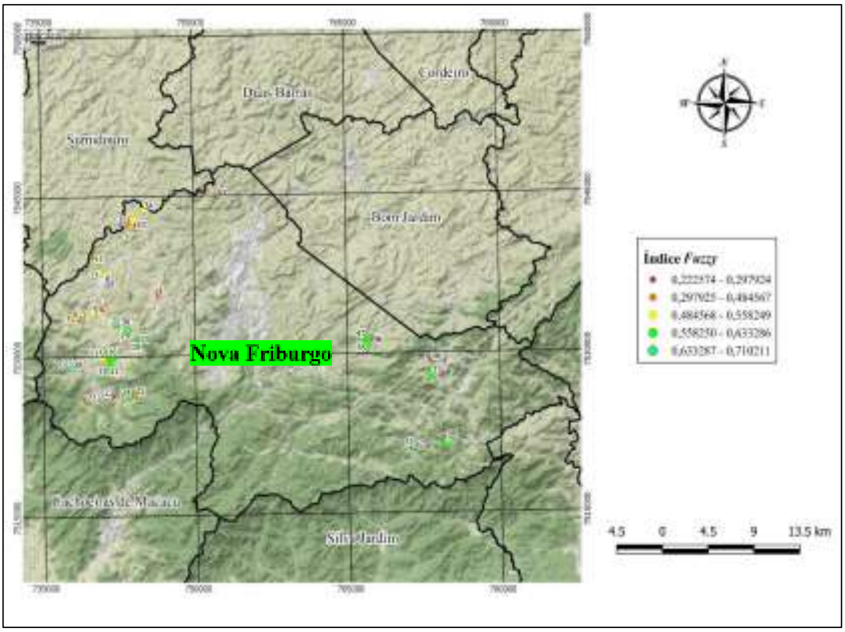

Fig.4 Spatial representation of the fuzzy index of agroecological transition of the production units of the family farmers interviewed in Nova Friburgo. On the right, at the bottom, the map of Brazil, with emphasis on the state of Rio de Janeiro, and at the top, this state is enlarged with emphasis on the municipality of Nova Friburgo, which is highlighted on the left with marked points of the analyzed agricultural production units.
Source: The authors; IBGE (2016) [11].

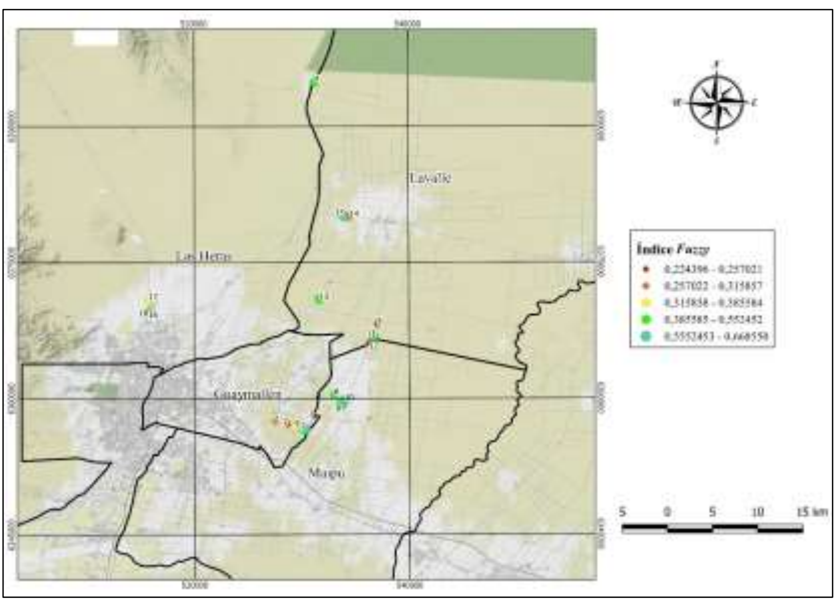

Fig. 5. Spatial representation of the fuzzy index of agroecological transition of the production units of the family farmers interviewed in Mendoza. On the right, at the bottom, the map of Argentina, with detail for the province of Mendoza, and at the top, this province is enlarged with emphasis on the visited region, which is highlighted on the left with marked points of the analyzed agricultural production units. Source: The authors; IGN (2021) [12]

4. Conclusion

The evaluation of agroecological behavior models demonstrated the conceptual effectiveness of the fuzzy model applied in monitoring and evaluating agroecological transition processes. The results revealed that there are some indicators or attributes that require immediate attention, enabling predictions of how these processes may evolve, providing decision-makers and policy-makers with a new approach to monitoring and evaluating the possible development of agroecological transition under current conditions, allowing for adjustments that favor its better evolution.

Therefore, the article proposes practical recommendations to accelerate the change in behavior of farmers towards more sustainable production systems. The focus is on production units of families inclined to adopt them, with a high possibility of ensuring increased productivity and sustainable income. Thus, the technical team can advise and provide technologies that promote continuous improvement processes.

The goal is to develop a replicable model of engagement, learning, and support, fueled by digital tools focusing on agroecological and social practices. Additionally, with data intelligence, it is possible to assist in integrating stakeholders in production chains, increasing the frequency of contacts between technicians and farmers, facilitating the diagnosis of challenges and personalized recommendations.

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