

# **Comparative analysis of sustainability assessment methods in agroecosystems**

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**ABSTRACT**

*The aim of this work was to compare and analyze three different methods of the sustainability evaluation in agricultural systems, such as the Indicateurs de Durabilité des Exploitations Agricoles (IDEA), the weighted Assessment of environmental impact of New Rural activities (APOIA Novo-Rural), and the indicators of sustainability in Agroecosystem (ISA). Those methods were compared by two criteria. The first one relates to the distribution of sustainability indicators into categories (Endogenous System Operation, Endogenous Resources, Exogenous Systems Operation, and Exogenous Resources) and elements (technical, socioeconomic, natural and cultural resources). The second one involves the conceptual approaches of each method towards the concept of sustainability, objective and target audience, adoption of the systemic approach, level of stakeholder's participation, level of adequacy, and method flexibility in different realities. The indicators set of each method, although quantitatively different, consider the diversity of elements that involve the agricultural systems. The IDEA method concentrates its indicators on the Endogenous System Operation category, while the APOIA Novo-Rural and the ISA methods concentrate their indicators on the Endogenous Resources category. The IDEA method directs the assessment to the awareness of the environmental processes that surround the agricultural activity in the property. On the other hand, in the APOIA Novo-Rural and the ISA methods, the reflective practice is fostered from impacts on the environment, and can be improved by extension actions. The main difference presented among those methods is the integrative evaluation of the indicators as well as trade-offs involved.*

**Keywords:** APOIA Novo-Rural methods. Agricultural sustainability. IDEA methods. Indicators of sustainability. ISA methods.

## **1. Introduction**

The term sustainability assessment designates the set of interests mediated by the sustainable development concept, whose main definition implies the ability to use natural resources by current generations without compromising future generations (CMMAD, 1991). Sustainability assessment is a method widely discussed and propagated as an effective action to stimulate the development of programs and policies that guide the promotion of sustainable agricultural systems (Binder et al., 2010).

The use of methods for assessing sustainability in agroecosystems helps to define and analyze the environmental performance of production systems, based on the structuring and data interpretation, which reflect the experiences of farmers and the type of relationship they have with their system. Nevertheless, the assessment of sustainability in agroecosystems is one of the most complex types of methodology, not only because agriculture involves multidisciplinary aspects (environmental, economic and social), but also due to the variety of cultural and functional elements that surround it (Sala et al., 2015; Binder et al., 2010; Binder and Wiek, 2006).

Among the innumerable initiatives available to assess sustainability in agricultural systems, the following stand out: Sustainability Indicators of Agricultural Explorations – IDEA (Vilain, 2008), developed by French researchers in order to offer a diagnosis of agro-environmental, socio-territorial and economic sustainability at the rural property level; the Weighted Assessment of Environmental Impact of New Rural Activities – APOIA Novo-Rural (Rodrigues and Campanhola, 2009) and Indicators of Sustainability in Agroecosystem – ISA (Ferreira et al., 2012), both developed in Brazil.

The sustainability assessment methods vary according to the assessment objectives set by its developers, and may present indicators with common or even divergent characteristics. Given this and the different types of existing agro-ecosystems, the choice of the evaluation method must be appropriate to the objective and to the peculiarities of the local reality to be studied, with easy validation and interpretation.

Thus, in order to compare three methods of assessing sustainability at the rural property level: IDEA, APOIA Novo-Rural and ISA, the present study was developed, aiming to characterize the components of each method analyzed.

## **2. Material and methods**

To compare the methods IDEA, APOIA Novo-Rural and ISA, two methodological criteria were used: The first was the distribution of sustainability indicators in categories and elements proposed by Camino and Müller (1993) and; the second makes use of Binder's conceptual approaches, according to Feola and Steinberger (2010).

In the first criterion, the sustainability indicators were separated and distributed into assessment categories and elements. The categories and elements are important aspects of the sustainability analysis in agroecosystems, as they represent the outline of how sustainability indicators were conceived and organized (Camino and Müller, 1993). By this criterion, there are four categories: endogenous system operation; endogenous resources; exogenous system operation; and exogenous resources.

The endogenous system operation refers to the activities carried out within the analyzed system and shows whether the management of the agroecosystem is compatible with the sustainability guidelines.

Endogenous resources correspond to the structural resource base that belongs to the analyzed system, with indicators that show whether this system negatively impacts or improves the agroecosystem resource base. The exogenous systems operation is characterized by functional activities external to the agroecosystem, but which maintains close relationships, affecting and being affected by the system (Daniel, 2000). Exogenous resources correspond to resources external to agroecosystems. Each category is subdivided into elements. These elements are related to the technical operations of agricultural activities execution and to the resources used (water, soil, air, climate, vegetation, etc.), not only of the system under evaluation, but also of its surroundings.

Then, the percentage of indicators present in each category was calculated. Some sustainability indicators, adopted in the evaluated methods, are composed of different measurement parameters, so that the result expressed by that indicator corresponds to the sum of several parameters. For these cases, the parameters were disaggregated, being considered as separate indicators and thus it distributed within each category. This technique is made feasible to identify with greater reliability the elements of greatest concern in the methods. The indicators obtained by mathematical expressions, such as proportion (cultivated area / total area, for example), were maintained as they were.

In the second criterion, the methods IDEA, APOIA Novo-Rural and ISA were compared by their conceptual execution way. For this, the approaches adopted by Binder et al. (2010) were used sustainability concept; objective and target audience; systemic approach adoption; stakeholder participation level and adequacy level. Through this approach, the sustainability concept refers to the sustainability understanding that is reflected in the indicators and it is determined in the results interpreting process. The objective and target audience refer to the different directions listed by the methods, which may be more or less important in relation to an aspect depending on the method end users or target audience (farmers, agricultural technicians, public or private intuitions). The systemic approach adoption deals with the complexity interpretation involved in the agricultural system, which allows it to analyze the economic, social and environmental aspects, as well as its trade-offs. The stakeholder participation level refers to teams interested in the agroecosystem evaluating process (usually represented by farmers who are involved in the evaluation process) for the purpose of implementing or monitoring sustainable agriculture. Finally, the adequacy level refers to the method capacity to adapt to different realities, which may vary according to the analysis spatial scale (local, regional, national or international), to lead to different interpretations or to mask the results. The Binder et al. (2010) approaches aims to outline the conceptual basis of each method, its development process and evaluation process execution, in order to highlight the main differences between them (Cândido et al., 2015).

Thus, sustainability indicators and their conceptual approaches for identifying the objectives, weaknesses and sensitivity presented by each method were evaluated.

The IDEA, APOIA Novo-Rural and ISA methods were applied simultaneously in Rural Land Reform Settlements in the municipality of Simão Dias, Sergipe, Brazil, with two Settlements being selected: "Oito de Outubro" (10° 39' 85" S and 37° 44' 59" O) and "27 de Outubro" (10° 39' 03" S and 37° 42' 52" O). Both settlements produce corn grain (*Zea mays*) in rainfed systems, managed by family producers, mostly from the movement/group "Landless". For ISA application in "Oito de Outubro" and

“27 de Outubro” rural settlements, the seven sub-indices with 22 indicators were considered, except for the food security indicator around the homes due to collecting parameters impossibility (Silva, 2018).

### 3. Results and discussion

#### 3.1 Distribution of IDEA, APOIA Novo-Rural and ISA sustainability indicators by Categories and elements

The indicators distribution by categories and elements is shown in Table 1. The IDEA method concentrates its indicators in the endogenous system operation category (81%), while in APOIA Novo-Rural and ISA, most indicators are fit into the endogenous resources category (66.1% and 59.5%, respectively). This result shows the different directions given by each method to the sustainability concept, even though all of them have the rural establishment as a spatial scale level.

In the endogenous resources category, the IDEA has 9.5% of its indicators in the elements flora, landscape structure and cultural resources, focusing on the presence and extent of natural vegetation on the property, the presence of water sources (springs or rivers) and the enhancement of historic buildings, as environmental sustainability analysis. IDEA does not bring data obtained from soil and water analyzes to the evaluation process, which limits, in technical terms, the environmental impacts measurement on a time scale. On the contrary, APOIA Novo-Rural and ISA seek to evaluate soil productive capacity data through the soil chemical analysis and the surface and underground water quality. For both methods, analyzes of soil and water physical-chemical properties are adopted, according to current rules, procedures and technical limits in Brazil, confirming them as tools in the environmental management of agricultural properties.

**Table 1.** Distribution of IDEA, APOIA Novo-Rural and ISA sustainability indicators by Categories and elements.

Category	Element	Indicators Number		
		IDEA	APOIA	ISA
Endogenous resources	Soil	-	10	10*
	Water	-	14	8**
	Flora	2	3	3
	Fauna	-	2	-
	Air	-	7	-
	Landscape structure and	1	4	1
	Cultural resources	1	1	-
	<b>Total (number; %)</b>	<b>4 (9; 5%)</b>	<b>41 (66; 1%)</b>	<b>22 (59; 5%)</b>
Endogenous system operation	Management and technical performance	9	-	3
	Management and socioeconomic performance	25	19	10
	<b>Total (number; %)</b>	<b>34 (81; 0%)</b>	<b>19 (30; 7%)</b>	<b>13 (35; 15)</b>
Exogenous resources	Soil	-	-	-
	Water	-	-	-

	Flora	-	-	-
	Fauna	-	-	-
	Air	-	-	-
	Landscape structure and Cultural resources	-	-	-
	<b>Total (number; %)</b>	<b>1 (2; 4%)</b>	<b>1 (1; 6%)</b>	<b>1 (2; 7%)</b>
Exogenous system operation	Management and technical performance	-	-	-
	Management and socioeconomic performance	3	1	1
	<b>Total (number; %)</b>	<b>3 (7; 1%)</b>	<b>1 (1; 6%)</b>	<b>1 (2; 7%)</b>
Grand total of indicators		<b>42</b>	<b>62</b>	<b>37***</b>

\* Soil fertility indicator was analyzed by its respective 10 parameters; \*\* The Surface and underground water quality indicator were analyzed respectively by their 4 and 3 respective parameters; \*\*\* Total number of indicators considered for calculating the percentage. Adapted from Vilain (2008), Rodrigues and Campanhola (2009) and Ferreira et al. (2012).

It is worth mentioning that, in agricultural systems, the monitoring of soil physical, chemical and biological quality, as well as the characterization and monitoring of lakes, rivers and water sources must be part of the farmer's planning and consequently of a sustainability assessment program. Soil analysis is an important tool for productivity, profitability and the environment, which combined with other information, such as land use and occupation and climate characteristics, bring the farmer a better ability to manage the agroecosystem (IPF, 1998). In addition, Brazil has its own classification regarding the support capacity of land use (Lepsch et al., 1991), which can provide rational planning for it and guarantee the preservation of several endogenous resources.

In the APOIA Novo-Rural and ISA methods, soil analyzes are basically covered by the same chemical data, which evaluate the soil productive capacity through chemical fertility parameters. The same criterion is used for the water element, however the APOIA method presents the larger indicators structure for assessing surface water quality in relation to ISA, such as the dissolved oxygen, fecal coliforms, BOD5, pH, nitrate, phosphate, solids parameters totals, chlorophyll, conductivity and water visual pollution, as well as for groundwater quality, such as fecal coliforms, nitrate and conductivity. In the evaluation of the water quality, the methods only have in common the parameters of pH, fecal coliforms, Turbidity and Nitrate.

APOIA Novo-Rural was the only method to present indicators related to the Air element, with 6 indicators aimed at sensory evaluation of atmospheric pollution (Particles in suspension/smoke, Odor, Noise, Carbon oxides, Sulfur oxides, Nitrogen oxides and Hydrocarbons). In IDEA, atmospheric pollution is indirectly assessed in the Energy Dependency indicator, which assumes the use or not of CO<sub>2</sub>-generating energy sources.

The indicators related to the Fauna element in the Endogenous resources category were also prioritized only by APOIA Novo-Rural. The method evaluated the fauna corridors presence and existence of species threatened with extinction, especially after agricultural activity implementation. The fauna analysis has crucial importance in the assessing sustainability process in agricultural systems, since the use of pesticides associated with monocultures extensive areas can destroy natural habitats threatening the local

fauna and its trophic chains. This fact highlights that, among the evaluated methods, APOIA presents a broader view of environmental systems, giving it greater importance for defining what would or would not be sustainable.

The APOIA-Novo Rural method directs the assessment process towards the environmental impact caused by agricultural activities, adopting the situation before and after the implementation of rural activity as a period (Sanchez and Matos, 2012). APOIA-Novo Rural translates sustainability from the causes and consequences that agriculture and livestock have on natural resources and on the flora and fauna biodiversity. The ISA method also directs the indicators for assessing the environmental impact, and highlights the importance of sustainable agriculture in an assessment process that emphasizes the consequences agricultural activity execution on the soil and water natural resources. ISA focuses on the formation of more sustainable agricultural systems (Ferreira et al., 2012).

On the other hand, the sustainability assessment by the IDEA method is based on technical and socioeconomic conditions of agriculture and livestock, and how these are being developed on the rural property. Its indicators, concentrated on the endogenous system operation (81%), direct the main focus of the IDEA method towards practical agricultural actions that may or may not lead to environmental impact, consisting of its most evident and differential characteristic in relation to the other evaluated methods. The endogenous system operation category in the APOIA-Novo Rural method is covered by 30.7% of the method indicators, listed in the element Management and socioeconomic performance, which represents a concern in the evaluation process with the socioeconomic sustainability of rural properties. However, APOIA-Novo Rural fails to highlight aspects related to Management and Technical Performance as the inputs and energy source. In the ISA method, the endogenous system operation category concentrates 35.1% of the indicators, directing its evaluation to both elements (Management and Technical Performance and Management and Socioeconomic Performance) of this category.

Regarding the Exogenous Resources category, each method (IDEA, APOIA Novo-Rural and ISA) had only one indicator could be classified as relevant to this category. The indicators Social involvement of IDEA, Institutional relationship at APOIA Novo-Rural and Basic services available at ISA. These indicators represent the element Cultural resources and assess the social relationship that the producer and his establishment have with the surrounding communities and with access to technical and social assistance. As the evaluation spatial focus of the three methods is the rural property, in none of them there were indicators related to the Soil, Water and Air elements. That could be classified as relevant to the category Exogenous Resources, since the environmental effects external to the rural establishment limits are part of a larger spatial scale (regional, for example) not covered by the evaluated methods.

In the exogenous system operation category, the IDEA method has, in the element Management and socioeconomic income, the indicators: sales mechanism, sensitivity to quotas and subsidies and space accessibility, which corresponds to 7.1% of the indicators. These indicators assess, respectively, products commercialization, credit availability and infrastructure of access roads to the establishment, which are fundamental to the good activity economic performance and consequently to its sustainability. In this category, the APOIA Novo-Rural method is represented by the indicator marketing condition (1.6%) and the ISA, by the Conservation State of internal and external roads (2.7%). In this sense, the three methods

direct the sustainability assessment also to operational aspects external to the rural property, whose quality greatly influences the quality of technical operations and management carried out by the farmer.

### 3.2 Conceptual approach to the sustainability assessment methods (IDEA, APOIA Novo-Rural and ISA) in agricultural systems

Table 2 presents a simplified comparison of the approaches related to the operationalization of each evaluation method.

**TABLE 2.** Comparison between the sustainability indicators methods of Agricultural Holdings (IDEA), Weighted Assessment of Environmental Impact of Novo Rural Activities (APOIA Novo-Rural) and Agroecosystem Sustainability Indicators (ISA)

Analysis criteria	IDEA	APOIA Novo-Rural	ISA
Sustainability concept	Predefined concept based on environmental reproducibility, habitability and economic viability aspects	Pre-defined concept aimed at assessing the environmental impacts of Novo Rural emerging activities	Predefined concept and guided by the social, economic and environmental dimensions for a transition process
Objectives and target audience	Mediate through self-assessment a process of raising awareness among farmers for sustainable agriculture	Advising producers and decision makers on the environmental impacts assessment	Mediate through the management tool a transition process to a more sustainable agro-ecosystem
Systemic approach	It Adopts three sustainability scales (Agroecological, Territorial and Economic Partner) with no interactions and no trade-off between them	Considers the interaction between the indicators and between the five dimensions with trade-offs between them	It Adopts the socioeconomic and environmental dimensions considering the interactions between the indicators with trade-offs between them
Stakeholder participation	Farmer, teacher, student and technicians, with evaluation procedures pre-defined by specialists (top-down approach)	Farmer, manager or technical consultant. With assessment procedure with top-down and bottom-up approach	Farmer, external manager or technical consultant. Evaluation procedure with top-down and bottom-up approach.
Adequacy	Rigid and standardized structure that requires adaptation to different contexts	Rigid, computerized and applicable structure to any activity in the Brazilian rural environment	Rigid, computerized and sensible structure to different agroecosystems



Adapted from Vilain (2008), Rodrigues and Campanhola (2009), Ferreira et al. (2012) and Cândido et al. (2015).

### *3.2.1 Sustainability concept*

The three methods are basing on a sustainability-predefined concept. Although all methods have the guidelines proposed by Brundtland report (CMMAD, 1991) as a common reference point, the definitions adopted follow specific terms according to each method focus.

In the IDEA method, the normative approach (Sanchez and Matos, 2012) guides the sustainability concept, that is, hierarchical models bases the information. In this approach, the indicators are scored in priority order, observing the agricultural systems multidimensionality (environmental, social and economic). Additionally, these sustainability dimensions or scales are respectively based on three main aspects: Environmental reproducibility, Habitability and Viability. These aspects mean that a rural establishment must guarantee the environmental quality of natural resources, be habitable for the farmer and his family and be economically viable (Zahm et al., 2008).

In APOIA Novo-Rural, a systemic approach guides the sustainability concept. Here, the economic and social system is interpreted as an integral part of the ecosystem and the sustainability indicators are derived from critical points identified in agro-ecosystems (Sanchez and Matos, 2012), which generate or may generate some type of environmental impact. Thus, agro-ecosystem performance indicators that address environmental impacts and pressures on the environment and the possible improvements made in the agro-ecosystem form APOIA Novo-Rural (Rodrigues and Campanhola, 2003).

In ISA, a set of indicators that aim to direct agro-ecosystems to the transition process to a more sustainable standard support the sustainability concept (Ferreira et al., 2012). The tool has a normative character in which the social, economic and environmental dimensions address sustainability. These dimensions support elements related to planning, management, conservation, training, access and diversification.

The three methods have in common the combination of sustainability basic principles. In IDEA and ISA, these principles are multidimensional, while in APOIA Novo-Rural, these principles are multifunctional. In multidimensional principles, sustainability is subdivided and analyzed by dimensions (social, economic, environmental, cultural, political, among others) observing its scope and, therefore, the functions performed by each dimension. In the multifunctional principles, sustainability is analyzed from the main functions of the agricultural system, such as food security, biodiversity and natural resources conservation, landscape maintenance, socioeconomic and cultural quality.

The indicators matrix formulated by IDEA brings a well-defined and rigid concept of sustainability (Cândido et al., 2015). This matrix is presented in a scoring system that highlights the presence and trend of agroecosystem aspects associated with sustainability. The measured indicators are added in nine components and three dimensions (Agroecological, Territorial and Economic partner) and each dimension can reach a maximum of 100 points. The final sustainability of the evaluated property will be equal to the lowest score of the three dimensions, that is, the sustainability of a system will be equal to the lowest numerical score obtained by one of its dimensions (Binder et al., 2010).

The APOIA Novo-Rural and ISA matrix follows an even greater principle of sustainability concept definition and rigidity, by proposing a general environmental impact assessment from a standard or baseline

(benchmark). The scoring system is standardized between 0 and 1 and the system sustainability degree is given according to the reference value (0.7); if below, barely sustainable, if above the line, sustainable. However, Moraes et al. (2012) highlight that the existence of a single reference line in APOIA Novo-Rural limits the environmental impact interpretation, as it stipulates a pre-defined environmental standard, which may not correspond to the minimum expected situation by the rural establishment. The result obtained by ISA follows the same approach mentioned above.

### *3.2.2 Objectives and target audience (End users)*

Regarding the objectives, IDEA was developed to be a teaching tool for the implementation and awareness of the sustainability concept in farms, with a view to reducing the impacts caused by agriculture and livestock itself (Briquel et al., 2001). In this sense, the IDEA method is aimed at teachers and rural extension workers whose target audience is farmers.

APOIA Novo-Rural is a management tool for various rural activities (Rodrigues and Campanhola, 2003). The method is aimed at advising producers and decision makers on the environmental impacts assessment at the farm level, with the target audience of farmers themselves. It developed ISA as a tool for measuring economic, social and environmental performance on the rural establishment's scale (Ferreira et al., 2012). Thus, its objective is to assist decision-making by those responsible for productive activities for a transition process to a more sustainable agro-ecosystem, with the target audience of farmers.

The three methods assess sustainability on a local scale and target rural farmers themselves. Questionnaires addressed to farmers and field observation generate the information. IDEA presents a didactic / pedagogical characteristic of application that allows the farmer/manager himself to carry out the evaluation process. APOIA Novo-Rural and ISA, despite being easy to apply, need technical support in order to avoid the subjectivity in the information collection, mainly regarding the changes that occurred after introduction of the new activity (Rodrigues and Campanhola, 2003).

The analysis and interpretation of the sustainability assessment in the three methods are easy to represent. The quantitative indicators use allows the use of a radar type graph and histograms. The results aim to help farmers to reflect on their practices, giving guidance as to the need for rural property improvements, so it can be compared between properties or between properties groups. In addition, ISA generates a summary table for evaluating rural property, which can be used as a basis for generating a general report of the evaluated establishments set (Ferreira et al., 2012). This report can contribute in a general way to the socioeconomic and environmental interpretation of the agricultural system in a given location.

### *3.2.3 Adoption of the systemic approach*

The environmental systems understanding encompasses aspects related to human activities and how these activities cause disruption or impact to natural systems. The systemic approach is opposed to reductionism and it is used as a support notion to designate the whole set of relationships between parts that form a whole (Morin, 2005). From the systemic approach perspective, the sustainability assessment of agricultural systems encompasses the action of each element involved in production, such as those formed by technical and environmental resources.

In the IDEA execution, the elements are analyzed on independent and non-cumulative scales (Vilain, 2008), which separates it from the systemic approach integrative action. The indicators are grouped together forming indices within each component, which, in turn, are aggregated to generate the index corresponding to each sustainability scale. The values of each scale are analyzed individually without being added, so that there is no compensation from one scale over the other, which could mask the reality. However, although there is no generation of a sustainability index (value), the results of each scale can be analyzed in an integrated manner.

In ISA, its indicators exhibit systemic approach characteristics, despite being a normative method. The method seeks to cover several aspects that lead to the sustainable agriculture understanding. The three dimensions (Economic, Social and Environmental), proposed by the method, are analyzed individually and, later, added together to generate a sustainability index. From the generated index, sustainability is analyzed by observing the parts complexity of the system and the whole.

The APOIA Novo-Rural method uses the systemic approach in the sustainability assessment process and proposes the environmental impact integration to social and economic aspects in the evaluated dimensions. APOIA adopts five dimensions: landscape ecology; environmental behavior quality (atmosphere, water and soil); sociocultural values; economic values; and management/administration. Each dimension generates an index that, when grouped together, forms the general environmental impact index. This method considers the interaction between the indicators, with a focus on identifying and quantifying trade-offs between the different dimensions. The trade-off refers to the greater relevance that one method can attribute to one investigated system element than to another, through the multiple functions performed by agriculture. Thus, one of the difficulties of assessing sustainability with the systemic approach is in the operationalization of the system concept during the results interpretation.

The system conceptual notion adds a dynamic of complexity to the sustainability idea of agricultural systems, which challenges researchers and technicians to interdisciplinary work, breaking barriers between the different sectors that make up agriculture and livestock (Marzall and Almeida, 2000). The basic assumption of the systemic approach is environmental complexity (Sanchez and Matos, 2012). The complexity concept explains the system non-linearity, its dynamics and ability to recover after a disturbance. In agroecosystems, the various behaviors (balance and imbalance) that the system may present, over time, show its complexity, in relation to its initial conditions (balance) and disturbances (imbalance) (Silva Neto, 2009).

The systemic approach importance situated in the integrated understanding of the functional skills that represent each part of the system. In the IDEA method, despite being a normative method, its indicators have systemic characteristics that lead to integrated understanding of environmental, social and economic aspects of agriculture. Some indicators used in one scale can be repeated in another, presenting concern in showing that the same element can be influenced or may influence differently another system aspect. Analyzing the IDEA method, Cândido et al. (2015) pointed out that this method fails to present a systemic approach, as it does not promote the interaction between these parts, focusing on the dimension with the lowest score, despite having indicators that represent the different parts of the system. However, this condition can be circumvented from the interpretation given by the method researcher or executor, so that

one observes the influences that an element can produce in another element and, consequently, in the entire studied system.

In APOIA Novo-Rural, the elements systemic integration occurs from the indicators selection to the final aggregation of the environmental impact index. This effect of adding different natures elements in the same dimension is considered, by the authors of the method, as the great advantage in relation to other available methods (Rodrigues and Campanhola, 2003), because it breaks with the disciplinary analysis intertwining the anthropic interventions in the changes environmental issues.

#### *3.2.4 Stakeholder participation*

Stakeholders are the groups interested in the sustainability assessment process. In agriculture, farmers themselves, agricultural technicians, research institutions and/or governmental and non-governmental bodies (Cândido et al., 2015) form these groups. Stakeholder involvement can occur in all evaluation process stages, from creation (concepts definition, objectives, indicators selection and goals definition), application and monitoring or in just a few stages of this process. Regarding the stakeholders participation in the evaluation process, the methods can be classified in a top-down (from top to bottom) and bottom-up (from bottom to up) approach.

In the three analyzed methods, stakeholder involvement is limited to the stages of indicators application and monitoring. Farmer is responsible for providing the data and he can not classify it personally. In IDEA, a top-down perspective lead to definition of the objectives and evaluation criteria, that is, the evaluation criteria are critically reviewed by researchers and complemented according to theoretical concepts related to sustainable development (Binder et al., 2010). In APOIA and ISA, stakeholder involvement occurs both in the top-down type, derived from researchers, and in a transdisciplinary bottom-up process that concentrates the participation of various scientific areas interested in the evaluation, combining qualitative (interviews and sensory evaluation) and quantitative (linear programming) tools (Binder et al., 2010; Sanchez and Matos, 2012).

For the data provision in IDEA, as it is a self-assessment tool, the farmer's opinion is also included, through notes, as to the aspects that involve life and territory quality. Although the top-down process favors the comparison between the different systems, target audience low participation in the evaluation procedures definition is one of this approach disadvantages, making it difficult to execute the recommendations that make the systems more sustainable (Cândido et al., 2015).

#### *3.2.5 Suitability in different realities*

Agricultural systems are heterogeneous, formed by subsets that group different systems, abiotic factors (relief, geology, climate, hydrology) and biotic factors (living communities, plants and animals) as well as different use and socioeconomic exploitation forms (Bertrand, 2009). The adequacy levels of the sustainability assessment method are characteristics that allow its reapplication in different contexts. In this sense, the three sustainability assessment methods have rigid matrices, with pre-defined indicators and assessment system.

The IDEA indicators and calculations matrix presents a standardization adjusted to the French and European agricultural systems context, which makes it difficult to apply in other contexts without

adaptations. The IDEA method is flexible for adaptations, despite having a rigid matrix, with its application reports in countries such as Tunisia, Mexico and Brazil (M'hamdi et al., 2017; Sala et al., 2015; Jesus, 2003). For its reproduction within the Brazilian context, adaptations in some indicators calculation systems were necessary, as well as indicators exclusion due to measurement or estimation difficulties or not being suitable for Brazil (Jesus, 2003).

On the other hand, the APOIA Novo-Rural and ISA matrices were developed and validated in Brazilian agroecosystems. Despite this, there are reports on the need to adapt the method to different contexts in Brazil, due to the great environmental, social and economic diversity. Pereira (2008) and Morais (2010) reported the needs for adaptations of APOIA Novo-Rural. These authors mainly highlighted the need for adjustments in the social indicators parameters in order to include different systems, especially family members. Since 2009, the ISA has been applied by EMATER technicians in several municipalities in the Minas Gerais State and it has shown sensitivity to Brazilian inter and intraregional variations (Ferreira et al., 2012).

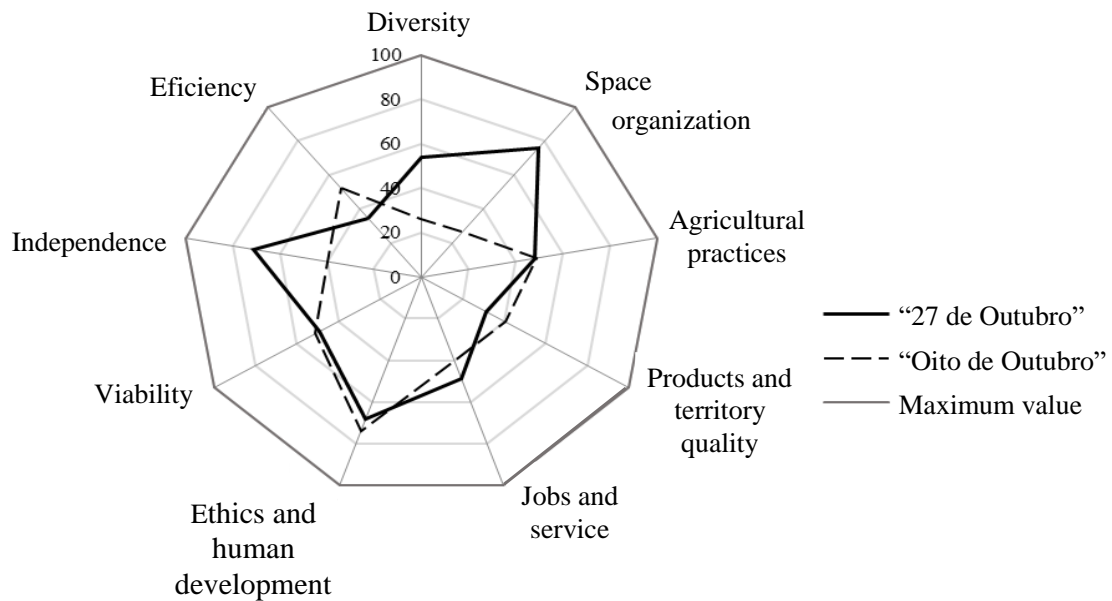
### 3.3 Application of IDEA, APOIA Novo-Rural and ISA methods on corn exploration in the Sergipe State

Para a realidade destes Assentamentos, o método IDEA necessitou de adaptações nos indicadores A9, A12, A14, A15, A18, B15, C1 e C4 e exclusão dos indicadores B12 (Contribuição ao equilíbrio alimentar mundial) por não ser aplicável ao Brasil e C5 (Transmissibilidade) pela ausência de dados e, por ser, parcialmente, contemplado no indicador B11 (Perenidade prevista).

For these Settlements reality, the IDEA method required adaptations in indicators: Legal contribution to environmental issues in the territory, Fertilizing, Pesticide, Veterinary treatment, Energy dependence, Work intensity, Monthly economic viability (R\$) and Contribution of external rents; and exclusion of indicators: Contribution to world food balance, as it is not applicable to Brazil, and exclusion of Transmissibility, due to the lack of data and, partially, being included in indicator Expected duration.

The “Oito de Outubro” settlement has its sustainability limited by the Agroecological Scale (Diversity, Space organization, Agricultural practices) that obtained the lowest score (34/100), while the “27 de Outubro” settlement has its sustainability limited by the territory social scale (products and territory quality, jobs and services, ethics and human development) in 49.3 out of 100 points (Figure 1). The “Oito de Outubro” settlement properties have their activities related to the corn and livestock cultivation, which limits the diversification and ecological balance of the cultivated area. The “27 de Outubro” settlement properties are mainly affected by the landscape low quality around the residences, the lack of access to basic sanitation and garbage collection services and low capital potential invested in production.

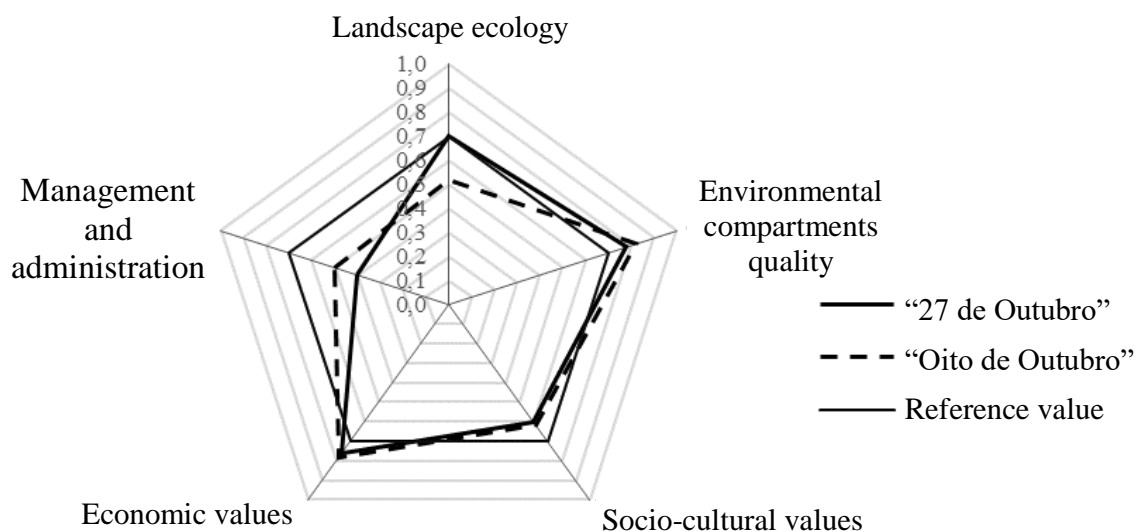
**Figura 1.** Sustainability assessment by different indicators in the IDEA method for “Oito de Outubro” and “27 de Outubro” rural settlements, in the Simão Dias county, Sergipe, Brazil.



Source: Santana (2019)

The APOIA Novo-Rural application in the “Oito de Outubro” and “27 de Outubro” rural settlements properties showed the Environmental Impact Index of the activity of 0.6 (below the reference value 0.7) being considered an unsatisfactory sustainability level (Figure 2), especially in the dimensions that contemplate the sociocultural values and, management and administration (Araújo, 2018). These limitations are related, respectively, to the producer’s qualification and the lack of financial control that provides better properties performance. APOIA Novo-Rural showed the need to improve technical monitoring in the cultivation stages for all properties, given the economic importance of corn for the studied properties.

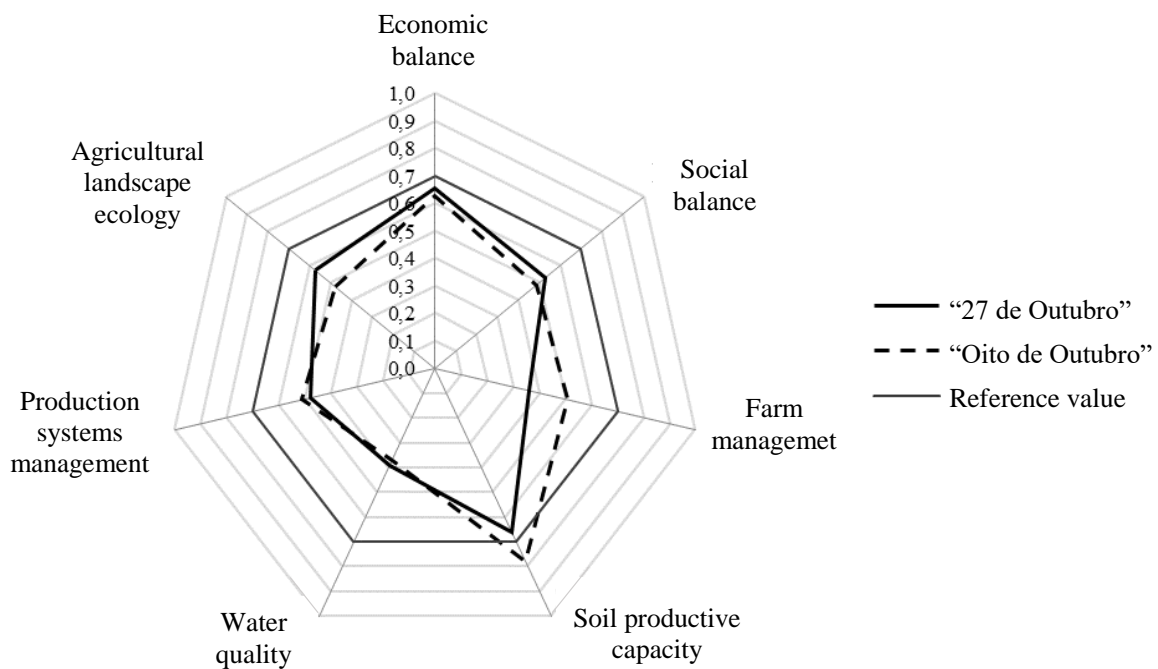
**Figura 2.** Sustainability assessment by different indicators in the APOIA Novo-Rural method for “Oito de Outubro” and “27 de Outubro” rural settlements, in the Simão Dias county, Sergipe, Brazil.



Source: Santana (2019)

The general sustainability index obtained by the two settlements was 0.5 (below the reference value of 0.7), which showed a fragility in the level of sustainability (Figure 3), mainly related to the sub-index water quality and management rural establishment, emphasizing the lack of technical assistance to farmers.

**Figura 3.** Sustainability assessment by different indicators in the ISA method for “Oito de Outubro” and “27 de Outubro” rural settlements, in the Simão Dias county, Sergipe, Brazil.



Source: Santana (2019)

#### 4. Conclusions

The comparative analysis of the sustainability assessment methods (IDEA, APOIA Novo-Rural and ISA) shows that each of them presents a multidimensional structure of agricultural sustainability. The set of indicators for each method, although they are quantitatively different, contemplate the elements diversity that involve agricultural systems.

The different elements (management and technical performance, management and socioeconomic performance, soil, water, air, landscape structure and cultural resources – Table 01) within the different dimensions of each method evaluation provided good conditions for the analysis and research of the agroecosystems involved in this comparative study. The performance characterization of agricultural properties and their representations are the main strengths, because it takes the farmer to a critical view of his own property, made possible by the holistic view.

The three evaluated methods proved to be particularly interesting as tools of reflective practice for inserting sustainability in agricultural systems, especially at a local scale. IDEA, as a pedagogical tool, directs the assessment towards the greatest possible awareness of the environmental processes surrounding rural property. In APOIA Novo Rural and ISA, reflective practice is encouraged by final report preparation

that shows, to the farmer/manager, his activity impacts on the environment, being susceptible to extension actions for improvements. A common characteristic among the three analyzed methods are the provided scenarios, which are subject to comparisons and future analyzes, providing support to decision making.

The main difference exposed by the methods is in the indicators integrative assessment, as well as the trade-offs. ISA and APOIA Novo-Rural make an explicit integrative assessment between social, economic and environmental indicators and with trade-offs between them for the elaboration of an environmental impact index. In contrast, IDEA does not have an integrative relationship and there is no trade-off between the agro-environmental, socio-territorial and economic dimensions.

The advantage of IDEA, in relation to ISA and APOIA Novo-Rural, is its didactic structure, which favors the evaluation in a greater number of locality or region rural properties, being able to be evaluated together and compared among themselves, with faster and cheaper evaluation. The disadvantage of IDEA, in relation to the other two other methods, is the data organization and structuring need to start the evaluation process, as well as the difficulty of obtaining some data, which limits some indicators operationalization, mainly due to the need for adequacy on international scale.

APOIA Novo-rural and ISA, despite having indicators validated worldwide, also present adaptation needs for other countries, since the parameters adopted are specific to Brazilian context.

The analyzed methods can complement each other in assessing sustainability processes of agroecosystems, since each of them explores its indicators distinctly, even though there are similarities between most of them.

The methods can potentially contribute to agricultural holdings improvement, by ordering and identifying both limiting and potential aspects of these holdings and their determining factors, bringing them closer to an environmentally balanced, economically viable and culturally accepted agricultural holding.

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