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Evaluation of the Agro-Ecological Sustainability of the Banana Production System: The African Food Company Case

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Abstract

The sustainability of agricultural activity, from production to marketing, has been discussed since the twentieth century until the present day. The present study aimed to evaluate the state of sustainability of the irrigated fruit agroecosystem (banana), as in the case of *The African Food Company (TAFC).* Exploratory and descriptive methods were used to assess the environmental, economic and social dimension of *TAFC's sustainability*. It was noticeable that the agroecosystem is environmentally sustainable despite having presented an indicator in a critical state (energy consumption). The economic dimension presented sustainable development indices (SDI S3) ranging from stable to excellent, which suggests that the agroecosystem contributes to the guarantee of its self-sustenance, as well as to the leverage of the local and regional economy. The social dimension presented indices ranging from stable to excellent, with only a low index in the level of education. In short, TAFC has a stable sustainability index, as it presents resilient, productive practices with a level of equity.

Keywords: Agricultural Sustainability; Agroecosystem; Agroecological Transition; IDEA; Sustainable Development Indexes.

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1. Introduction

Over the years, after the advent of the Green Revolution, agriculture ended up going through a process of modernization that was mainly caused by the chemical input industries, the maximization of production and profit, which brought numerous social and environmental problems [1]. This type of agriculture has been praised by some, due to the large production of food, the generation of wealth [2, 3], and pointed out by others as responsible for the cycles of degradation and poverty observed in large regions of the planet [4].

However, it should not be ignored that intensive agricultural activity has basically focused on the production of food, fiber and energy, aiming to meet, above all, the population increase and, consequently, the growth of consumption and human survival [5]. Several studies, addressing plant reproduction, have allowed the increase in agricultural production in several regions. In addition to this, intensive, or irrigated, agroecosystems have received different adjectives. There is talk of modern, intensive, commercial, conventional, technological, scientific, plantation agriculture, among other names [2, 3].

Along with these denominations, discussions about sustainability emerged, which bring to the debate the importance of including environmental, economic and social dimensions, having as a guiding axis the practices and management of natural resources that can outline sustainable agricultural systems [6]. These systems take into account the relationship between man and nature, that is, the interaction between the social aspects and natural resources of agricultural systems, defined as the set of activities carried out on site, considering biophysical and socioeconomic elements [5].

One of the alternative styles of agriculture to conventional agriculture, which is less harmful to the environment and capable of conserving soil, water and animal and plant genetic resources, conserving the environment and using appropriate, economically viable and socially acceptable techniques is organic agriculture [7].

Environmental sustainability occurs in the sense that the agroecosystem used must maintain, over time, its fundamental characteristics and interrelationships; the economic one, in the sense of providing constant and stable income; and social, in the sense that the management of natural resources must be compatible with the cultural values of the communities and groups involved, and must also be continuous over time [8].

In 2010, in the District of Guija – Mozambique, a premium organic banana production unit was established, with the aim of meeting the growing demand for the product, as well as elevating the local community through the creation of jobs, skills training and the introduction of new technologies [9].

In view of the uncertainty and to deepen and understand the socioeconomic and environmental relations derived from banana production in the Guijá Unit, this case study is proposed, aiming to measure to what extent the agricultural practices adopted in the banana production unit influence the sustainability of the agroecosystem both in the biophysical and socioeconomic spheres, over time (interaction of exhaustible resource management, income generation, direct impact on the local economy versus time). In this context, the present study aimed to evaluate the Agroecological sustainability of the banana production system – as in the case of The African Food Company. The specific objectives are: To characterize the environmental and socioeconomic aspects; Identify the level of sustainability of this agroecosystem, in order to generate information that leads to improvements in its management and management.

2. Materials and methods

2.1. Characterization of the study site

The African Food Company (TAFC), is located in the Administrative Post of Chivongoene, District of Guijá, Province of Gaza in Mozambique, 240 km north of the country's capital and with geographical limits to the north with the District of Chigubo, to the east with the District of Chibuto, to the south and southeast with the District of Chókwè and to the west with the District of Mabalane, with a surface area of 3589 km2, with geographic coordinates 24º25'09.12"S 32º56'27.42"E.

TAFC is an organic banana production agroecosystem occupying an area of 300 hectares, of which only 160 hectares are being explored. This agricultural project was established in 2010 to meet the growing demand for organic bananas and uplift the local community through job creation, skills training and introduction of new technologies, currently employing 209 workers, of which 105 are women and 104 men, It is important to note that 95% of the workforce are local workers.

The organic plantation received a grant from the Dutch government's Private Sector Program (PSI) and an approval from the Mozambican investment promotion agency (CPI) based on the environmental, commercial, socially responsible and sustainable nature of the agricultural project. Its products are sold in neighboring South Africa and on the national market, with plans to expand exports and opportunities for investors.

2.2. Data collection

To carry out this research, the IDEA method was used, which is based on the methodology described by [10], the method composed of Sustainable Development Indicators (IDS S3) which uses the Biogram with a systemic focus – scalar, multidimensional and intertemporal and the results were based on graphical representation – Biogram, enabling an analysis and a better understanding of the real state of sustainability of the agroecosystem The African Food Company (TAFC). In this context, structured interviews were carried out with workers, administrative staff, samples were collected and laboratory analyzes of water and soil and a non-participant observation script were carried out throughout the extensive area of the agroecosystem, with a view to collecting primary data for analysis. quantitative and qualitative regarding the environmental, economic and social dimension.

2.3. Determination of sustainability dimensions

To assess the sustainability of the agroecosystem in question, the dimensions where the indicators were defined were selected, which were used to calculate the IDS S^3, obtained through the arithmetic mean of the respective variables that make up each dimension, thus arriving at the indexes, operationalized in the Microsoft Excel 2016 spreadsheet [10]. The same dimensions, with indicators that were established to assess the sustainability of the agroecosystem, as well as the relationship function of each indicator, also consider parameters and sources.

2.3.1. Environmental dimension [A]

This dimension was measured using specific parameters linked to environmental aspects, namely: (i) water quality parameters, (ii) soil quality, (iii) energy consumption, (iv) soil management and (v) soil erosion, according to the methodologies described below:

a) Water quality parameters [A1]

To determine water quality parameters, samples were collected at three points, Point_1 – river, Point_2 – dam and mini-reserve and Point 3 – distributors, where the following parameters were determined:

(i) Water consumption – budgeted based on the amount of water used daily by the agroecosystem, considering liters per plant, with the parameter being an average of ≤ 30 liters/plant, according to [11]; (ii) hydrogen potential (pH) of water – measured according to the concentration of hydrogen ions H+, with permissible limits values ranging between 6.0 and 9.5 according to [12]; (iii) legal reserve area – counted according to the percentage of natural vegetation per hectare, with the legal limit being the parameter 20% ha., minimum of the total area [13], (iv) Electrical conductivity (EC) of the water; (v) Total alkalinity (CaCO3) of the water; (vi) Calcium (Ca+2), (vii) Sodium (Na+); (viii) Potassium (K+); (xi) Bicarbonate (HCO3-); (ix) (sulfate (SO42); (x) Chloride (Cl-), (xi) Soluble phosphate (P) and (xii) Total Organic Carbon ($gC/100g^{1-}$), (x) total coliforms (cfu/100ml) and, (xi) fecal coliforms (cfu/100ml), these parameters were measured, based on the methodology described by [12, 14] in line with reference MS nº 2914 of December 12, 2011 (CONAMA 357). In this context, water samples were collected simultaneously in a random manner, in 500 ml bottles throughout the extension of the agroecosystem in question, having been identified, packed in Styrofoam boxes and their analyzes were carried out in the Laboratory at Eduardo Mondlane University (UEM).

b) Soil quality parameters [A2]

They were sized by soil fertility parameters, where 16 units of soil samples were collected in 08 blocks of the total extensive area of the agroecosystem, at a depth of 0 – 20 cm and 20 to 30 cm from which they were also collected. and measured in the UEM Laboratory following its methodologies, where the following variables were analyzed (i) hydrogen potential (pHH2O &pHKCL) of the soil – evaluated according to the concentration of hydrogen ions (H+), with permissible limits values between 7.5 and 7.4, according to [12, 15] (ii) calcium (Ca) (cmolc.dm-3), indicated between 3.0 – 4.0; (iii) Magnesium Mg (cmolc.dm-3), desirable between 40 – 1.0; (iv) Phosphorus P (mg.dm-3), expected between 3.5 – 0.5, (v) Potassium (K) (mg), indicated between 300 – 500; (vi) sodium (Na) (cmol/kg), defined as less than 4; (vii) Types of fertilizer, indicated as organic, chemical and mixed; (viii) Soil Texture, between clayey, medium clayey and sandy; (ix) Exchange aluminum [meq/100g]; (x) Organic matter [%], classified as: low (<1.6) medium (1.6 – 3.0) high (>3.0), (xi) Organic carbon [g.kg-1] , being classified as low (<9.74 g.kg-1), medium (9.75 g.kg-1), high (>9.97 g.kg-1) (SANTOS and his colleagues, 2021) (xii) Electrical conductivity [mS /cm], being: low (<0.08 mS/cm), medium (0.09

mS/cm), high (>0.10) [16].

c) Energy consumption [A3]

This indicator was calculated by energy consumption in kilowatt-hours per year, with a parameter of 0.36 Kwh/ha./a.a[5];

d) Soil management [A4]

The measurement of this indicator followed three (03) criteria, namely: through collection, observations and notes on the variables used in the construction of this indicator, constructed during the interview in the agroecosystem. Firstly, the techniques used in management practices (variables) to control soil fertility were identified, according to the forms of fertilization, and finally the weighting of values was based on: 1, means use of chemical fertilization and green cover; 2, refers to the use of chemical fertilizers and green cover and a part, in agriculture, using mulch; 3, identifies the use of chemical fertilizers, green cover and mulch; 4, I defined the use of chemical fertilizers, green cover and mulch and a part, in agriculture, using manure; and 5, indicates the use of organic fertilizers, green cover, mulch and manure.

e) Soil erosion [A5]

The variables that were used to evaluate this indicator were weighted according to the occurrence of erosion, which were measured using the following values: 0, demonstrating non-occurrence; 0.4, representing the splash effect; 0.6, meaning the laminar phase, moderate taking the form of a groove; 0.8, indicating a compromising state taking the form of a ravine; 1, visualizing severe, having the shape of a gully.

f) Disposition of empty agrochemical packaging [A6]

The collection of information used to prepare this indicator was based on primary data, obtained using the participant observation method, which was based on the identification and recording of the different ways used by the agroecosystem regarding the disposal of empty agrochemical packaging.

For weighting, a scale adapted from [17] was used, aiming to guide agricultural systems on the correct destination of containers containing agrochemicals in agroecosystems. The variables used in the construction of this indicator were constructed and weighted according to the disposition of empty packaging, lid, plastic bag and ribbons, values: 0, indicates that reused and burned; 0.2, defines being burned; 0.4, scores when buried; 0.6 indicates that it is delivered to public collection; 0.8, represents that it is collected in a location in the farm for possible disposal; and 1 indicates that it is collected and delivered to the duly legal point, or sold to companies.

2.3.2. Economic dimension [E]

The economic dimension was measured using the following indicators: production (E1) – budgeted based on the volume produced, in tons, in the 2020 agricultural year; productivity (E2) – assessed through the production capacity of the agroecosystem, tons per hectare [18], taking as a parameter the production corresponding to the year; economic confidence (E3) – measured by weighing the importance of the net result of production, in the situation, when the price of products fluctuates more than 15% [19], and when the price of inputs rises in equal proportion, according to parameter weighting, 0 to 1 [20]; – external marketing (E4) – measured by the percentage of bananas sold; permanent employability (E5) – quantified by the percentage of employment generation in the agroecosystem with a formal contract.

2.3.3. Social sustainability [S]

The social dimension was measured using indicators: (i) education (S1) – calculated from the percentage of rural workers who had basic education training, in the agroecosystem; (ii) adequacy of own housing (S2) – estimated by the percentage of workers occupying their own home; (iii) use of personal protective equipment (PPE) (S3) – assessed the percentage of workers who use PPE [21]; accident occurrence (S4) – percentage quantified; access to labor justice (S5) – calculated by the percentage of access to labor justice by workers in agroecosystems.

2.4. Data processing

Data processing was based on the definition of sustainability, where the following characteristics were incorporated: agricultural sustainability, productivity, equity, in relation to environmental, economic and social dimensions, structured through fifteen indicators and respective indexes.

Their operationalization was based on computerized Excel 2016 spreadsheet packages, using the observed values method [10], where the maximum and minimum values are defined for all indicators.

For each indicator, a positive (+) or negative (-) relationship function was established, that is, the increase in the value of the indicator reflects a better or worse situation in the state of sustainability.

According to the methodology described by [10], the calculation of the index depends on the relationship between each indicator. According to the relationship function, different formulas are adopted. For example: for an index with values between 0 and 1, the higher its value, the better the state of sustainability of the Agroecosystem.

Therefore, an employability rate indicator, having a positive relationship (+) with the social equity process, had a higher index the higher its value. The opposite may occur with the number of low employability rates. In other words, the higher its value, the lower the index, since unemployment has a negative relationship with social equity. The relation function is differentiated by the signs + (positive) and – (negative).

Operationalization is done through the following equations:

Equation 1: Positive ratio function of the index

$$f(x) = \frac{x-m}{M-m} \qquad (1)$$

Equation 2: Negative ratio function of the index

$$f(x) = \frac{x-M}{m-M} (2)$$

Where:

x – Is the value corresponding to the variable or indicator;

m – Represents the minimum value of the variable in a given period;

M – Demonstrates the maximum level observed in a given period.

After operationalization, the indicator indices were calculated using arithmetic and weighted averages. Before, however, they were subjected to the relationship function: positive (+), when the increase in the value of the variable results in the improvement of the agricultural system; negative (-), when an increase in the value of the variable results in the worst of the agricultural system. For this, the procedure for adjusting the observed values was carried out, according to a scale along with the minimum value was 0 (zero) and the maximum was 1 (one), with an increasing variation of levels, which symbolizes the state of sustainability: collapse, unstable, stable and optimal, as shown in figure 1.

Collapse	**Critical**	**Unstable**	**Stable**	**Optimal** **1**
RedRed	**Orange**	**Yellow**	**Blue**	**Green**
0	**0,2**	**0,4**	**0,6**	**0,8**

interrelationships between the different dimensions, making it possible to carry out

Figure 1: Levels of the sustainability state from the perspective of Biogram

Source: [5].

Comparative analysis integrating economic information, environmental and social issues, as described in table 1.

Table 1: Multidimensional systematization, indicators and indices of TAFC's sustainability status

DIMENSIONS	INDICATORS	Index
Environmental (A)	A1. Irrigation water consumption (m³/month)	1.00
	A2. Water quality parameters (Liter/plant/day)	1.00
	A3. Energy consumption (Kwh/month)	0.03
	A4. Soilfertilityparameters	0.73
	A5. Soil management	0.87
	A6. Erosion	1.0
	A7. Use ofbiochemicals	0.51
	A8. Legal reserve area	0.78
	A9. Disposition of empty agrochemical packaging	0.81
Environmentaldimensionsustainabilityindex		0.75
Económica (E)	E1. Productivity (Kg/ha)	0.92
	E2. Economicconfidence	0.84
	E3. Commercialization	0.75
	E4. Phytosanitaryoccurrence	0.75
	E5. Management andaccounting	0.80
EconomicDimensionSustainability Index		**0.81**
Social (S)	S1. Directemployment	0.92
	S2. Worker's place of origin	0.95
	S3. Precariousnessofwork	1.00
	S4. Use of PPE by workers	1.00
	S5. Education – knowing how to read and write	0.22
Social DimensionSustainability Index		0.82
GENERAL INDEX		0.79

3.1. Environmental Dimension and indicators

In order to make the relationship between society, natural, biotic and abiotic resources of the ecosystem, specifically the soil, water and air of the Agroecosystem under study, its results and their respective indicators are presented below.

3.1.1. Water quality

a) Water consumption – A1

Based on the measurement of water consumption (Liter/plant/day), obtained through the calculation of the flow volume (m3/ha) of the motor pump, irrigation hours, number of plants per hectare, of the agroecosystem in question, it is characterized by spray irrigation, with plants being irrigated two (2) times a week in the cool season and three (3) times a week in the hot season for two hours. In line with what was described by [11, 22], the banana plant in semi-arid areas requires an average of 30 liters/plant per day on sunny days, as well as [23], elucidates that irrigated agriculture is responsible for the greatest global water demand and, in addition, the use of water in agriculture is also related to post-harvest processing and, in many cases, involves waste.

In this regard, the relationship function of this indicator is negative (–), since the lower the irrigation water consumption index (negative) above the parameter 30L/plant/day, the better (positive) the resilience capacity will be. both from the plant and from the soil and water. In this case, indicator A1 measured the state of sustainability, considering it excellent, with an index of 1.00, as the irrigation process is not carried out daily regardless of the time of year, thus making it sustainable with regard to the water consumption parameter, but With this result, it is assumed that there is no waste of water, energy, loss of nutrients due to water runoff and soil aeration, thus contributing to increased water use efficiency, productivity and benefit/cost return as described [20].

b) Water quality parameters – A2

Based on Ministerial Diploma l No. 180/2004 of September 15, 2004, the water quality values of the agroecosystem present an ideal quality for irrigation, banana processing and for human consumption. The index corresponding to the negative relationship function is considered optimal for the use of water in the agroecosystem.

Since water is the main strategic input for the development of irrigated banana agriculture, both the quantity and quality of water are relevant in agroecosystems, submitted to banana fruit growing, which is considered a major consumer of water [11]. The best quality water produces better results or causes fewer problems to the irrigation system and the environment [11].

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c) Energy Consumption – A3

In the agroecosystem under study (TAFC), the total amount of energy consumed per month is 4905.9 Kwh after subtracting 18% destined to the processing, packaging and shipment of bananas, as described by [24]. This value corresponds to the percentage of the actual efficiency parameter, which corresponds to the electricity consumption considering the need of the punctual irrigation system (sprinkler) of approximately 1355 kwh/ha/year. When this index was converted from monthly and daily energy quantity, the value obtained was 0.3, which is considered critical.

The achievement of a critical index should possibly be influenced by the installed irrigation system, as it is based on micro sprinklers, although irrigation is not carried out daily, but a daily consumption per hectare was verified for tropical zones, as is the case of the study site of the present research, above that recommended by Reference [25], corresponding to 3.72 Kwh/ha./day, since in the present study a higher consumption was obtained in the present research, being equal to 4.66 Kwh/ha./day.

Furthermore, it is important to highlight that in the agroecosystem, high energy consumption is possibly associated with the work of preparing new areas for cultivation, which forces managers to use the mechanized system for the configuration of the fields (installation of an irrigation and transport system, opening of drainage ditches, among other related works), that is, consumption is not only related to current production. It is necessary to refer to the energy consumption for the processes of harvesting, washing, packaging, storage and conservation of bananas.

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3.1.3. Soil fertility parameters

The results regarding this parameter analyzed the physical-chemical parameters capable of supplying plants with essential nutrients and the appropriate proportions for development, aiming at high productivity for fruit growth. In this context, the variables used for this indicator were: hydrogen potential, pH (in water 1:2:5); pHKCl (1:2:5); EC (1:2.5) [mS/cm], Calcium, Ca [meq/100g]; phosphorus, P [mg.dm-3], potassium K+ [meq/100g], Organic Compounds, C.O. [%], Organic Matter, [%], Magnesium, [meq/100g] and sodium, Na+ [meq/100g]. (ix) Exchange aluminum, (x) Organic matter [%], (xi) Organic carbon [%], (xii) Electrical conductivity [mS/cm].

Given the positive relationship function (+) of this indicator, the index was calculated using equation 1, resulting in a stable index corresponding to 0.73.

It is known that despite the great demands of the banana tree, the low levels of nutrients in some soils mean that its cultivation in irrigated systems is not sustainable, making it necessary to apply a high level of fertilizers and water so that there is greater efficiency in the absorption of nutrients. , with dependence on external inputs. But when considering the indicator obtained, it exposes good management practice in soil management.

a) Nutrient composition of the soil

The nutritional composition of the 08 sampling points evaluated in the present research, in this regard, as recommended by [11, 12], the permissible limits of pH in H2O vary between 7.5 and 7.4, which can be It is clear that the majority of points presented a pH outside the established range, differing in tenths from the ranges established for banana production at the two depths evaluated. When interpreting the results obtained in this research, it can be concluded that it presents a pH of calcareous soils, as [12], states that a pH in the range of 7 to 8 indicates calcareous soils.

Regarding the relationship between pH in H2O and pH in KCl, [26], state that the two types of pH have a positive relationship, because if the pH in KCl is lower than the pH in H2O, it is indicative of the presence of exchangeable aluminum in the soil, and if the pH in KCl is higher, the soil is electro positive, that is, positive charges predominate. In this regard, in the eight study points of the present research, it was found that the pH in KCl presented low values in relation to the pH in H2O, therefore, it can be concluded that the soil probably presents high levels of exchange Aluminum or exchangeable.

The electrical conductivity of the soil varied between 0.11 and 1.27 mS/cm in the eight study points and at both depths, with point 1 at a depth of 0-20 cm showing the highest value and point 7 at a depth of 0-40 cm at presented a lower value, taking into account that the EC is related to the water content present in the soil, this change is related to the dilution of the salts in the solution [27].

For the values of macronutrients (Ca, Mg, P and K) a variability was observed in the values obtained in the eight points studied in this agroecosystem, at both depths (0-20, 0-40 cm). Overall, the average Ca values ranged from 8 to 62.8 [meq/100g], Mg values ranged from 1.2 to 3.2 [meq/100g], P ranged from 0.195 to 6.566 [meq/100g] and K ranged from 0.31 to 3.27 [meq/100g]. Therefore, it can be seen that at some points the values are very high in relation to others, which may be related to the physical-chemical components present in each area of the blocks studied and the composition of the irrigation water. In addition to this, Fernandes and his colleagues, (2008), reports that the increase in macronutrients is directly influenced by the chemical composition of the water used in irrigation, which contains high levels of Ca and Mg, and can also be influenced by annual phosphate fertilizers, which increase the availability of these nutrients to plants.

About O.M. and O.C., there was also a great variability between the points, the O.C. varied from a percentage of 0.29 to 1.41, with Point 1 presenting the highest value and Point 6 presenting the lowest value. For O.M., there was also a large variation between 0.5 for point 6 and 2.93 for point 1, this variability is possibly linked to the distribution of organic particles in the areas that make up the banana planting blocks, because in some areas there is greater plant growth in relation to others, thus contributing to the greater availability of organic compounds in the soil.

b) Soil types

The study area in the present research presented varying percentages of soil, most within the recommended parameters, as described by [28], except point 6 which presented a greater amount of sand in its composition, which caused several losses and difficulties. In the growth and development of banana trees, as according to the same author, sandy soils should be avoided, as they have low fertility, low moisture retention power and favor the spread of nematodes.

However, contrary to what was described by [28], at this point a banana is produced with enviable characteristics, whether in its appearance, weight, size and flavor, despite being a portion that in recent months has not benefited from any cultural treatment, including fertilization and irrigation, that is, it is practically abandoned. This is possibly linked to the cycling of nutrients in the soil between the naturally predominant species and the main crop of interest.

3.1.4. Soil management – A5

Regarding the description of agricultural cultivation practices in TAFC, it was found that the predominant practices are: (v) use of organic fertilizers, green cover, mulch and manure.

These practices may have contributed to the parameter relationship function (+), with an index considered optimal corresponding to 0.87, which contributes to the trend of irrigated banana production agroecosystems Reference [29]. For this author, the aforementioned agroecosystems have raised questions regarding how to manage the soil, as carrying out agricultural practices can compromise long-term sustainability. For the state's agroecosystem, an index of 0.87 in “10 years” of activity can be considered sustainable.

Reference [30] consider that banana cultivation demands large amounts of nutrients to maintain the good development of the plant and cultivation, with potassium and nitrogen being the most required. And, integrating chemical and organic fertilization (mulch) into the management may signal possible improvements in soil fertility, since the use of mulch, in management, consists of covering the soil with grass, straw, bark, crop residues, plant, enabling the reduction of evapotranspiration and erosion processes, maintaining the humidity of the irrigated soil for longer, thus contributing to the property of environmental resilience, which is practically recommended for the majority of permanent crop soils.

3.1.5. Erosion – A6

The assessment of the action of surface runoff of rainwater and irrigation in the agroecosystem based on a collection of primary data, taking into account the negative function (-), resulted in an index equal to 1, which is considered optimal.

The occurrence of erosion was not verified throughout the entire extent of the agroecosystem and the data obtained through interviews indicate that the occurrence of erosion has never been observed in the history of the agroecosystem. This is possibly influenced by the type of relief that abounds in the agroecosystem, whose slope is between 0 and 3% [11].

On the other hand, the practice of green mulch, which plays a role in soil surface stability, and the existence of drainage ditches can contribute to the non-occurrence of erosion and can contribute to its resilience [11].

3.1.6. Use of agrochemicals – A7

Based on interviews, field management and participant observation, it was possible to verify that agrochemicals are used, mainly fungicides, with the aim of controlling yellow Sigataka, a disease caused by the fungus Mycosphaerellamusicola Leach. According to [31], this disease is characterized by infecting banana leaves, which dry out, causing a reduction of approximately 50% in production.

Based on the variables that constitute indicators on the issue of the use of agrochemicals using the negative relationship function (-), an index corresponding to 0.51 is observed. The value results from the relationship between the amount of fungicides used per hectare, which is 2l/ha and is within the range recommended by [32].

3.1.7. Legal reserve area – A8

According to [13, 70, 71], the existence of a legal reserve area within the agroecosystem is mandatory, and an area equal to or greater than 20% of the total area of the agroecosystem is recommended due to the guarantee of greater biodiversity. In the agroecosystem under study, a stable index corresponding to 0.78 was obtained, combined with this, as also referenced by [13, 69], banana agriculture is sustainable over time, the finiteness of natural resources must be considered, which implies the maintenance and conservation of the legal reserve area, contributing to the maintenance of local biodiversity. Due to preservation, maintenance and conservation of forest resources and other forms of native vegetation that correspond to 20% of the hectares. Based on the index obtained, it can be seen that TAFC ensures the sustainable economic use of natural resources to assist the conservation and rehabilitation of ecological processes and promote local biodiversity, as a way of providing shelter and protection for wildlife. and native vegetation.

3.1.8. Disposition of empty agrochemical packaging – A9

This indicator is characterized by the use of primary data based on interviews and field observation, where the indicator was weighted following the scale established by [32, 68, 69], which addresses the irregular disposal of agrochemical packaging with the aim of guiding agricultural systems on the correct disposal of containers containing agrochemicals.Based on the indicator's relationship function being positive (+), an index of 0.81 was obtained, as the agroecosystem gathers the packaging in a location within the agroecosystem for possible disposal. This practice raises a perception of optimal sustainability, supported by [25, 67, 68], who mentions in his study that packaging cannot be disposed of in the open, burned or buried, as they can compromise the soil, river water, groundwater, fauna, people, in short, the environment.

3.1.9. Synthetic sustainability index S^3 of the environmental dimension

The Biogram (figure 2) reveals that indicator A3, energy consumption (Kwh/month), has its index axis 0.03 less expanded, demonstrating critical sustainability. The remaining indicators present indices that vary from stable to excellent, as looking at the biogram they appear more expanded, especially indicator A6. (Erosion) and A1. (Water consumption), with maximum rates, demonstrating a stable situation of the agroecosystem.

The integrated and sustainable development index (S^3) tends to approach the ends of the Biogram, demonstrating a situation of stable sustainability of the agroecosystem, as it approaches the ends of the axes that quantify higher levels of sustainability and performance of the agroecosystem.

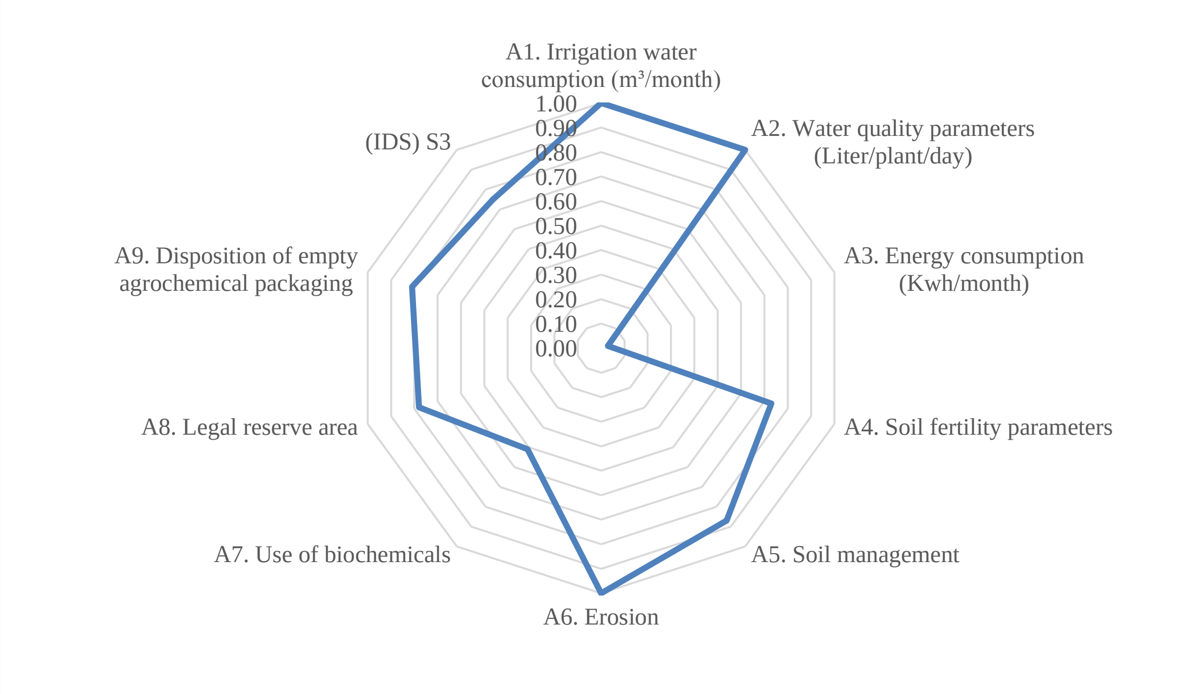

Figure 2: Biogram, synthetic sustainability index S^3 of the environmental dimension

3.2. Economic dimension and indicators

The results regarding the potential of TAFC, based on the ability to innovate, diversify and rationally articulate natural and economic resources with the management of work and income opportunities, strengthening people's well-being through banana cultivation, interacting and respecting the conditions of other dimensions – environmental, social and political-institutional are presented below, determined based on six indicators, namely: (i) Productivity in tons – E1; (ii) Economic confidence, inferred by weighting the importance of the net production result – E2; (iii) Marketing – measuring marketing channels – E3; (iv) phytosanitary occurrence – quantified through the occurrence of yellow Sigatoka disease – E4; (v) benefit/cost – calculated the quotient of this relationship using an index greater than 1 as a parameter – E5 and (vi) rural management and accounting – measured by the occurrence index using the highest index as a parameter – E6.

3.2.1. Productivity – E1

Its measurement was based on the relationship between production and size of land in use and/or planting in hectares, providing information on the production capacity of the agroecosystem in ton/ha.

The relationship function of this indicator is positive (+), because when there is an increase in production per hectare, productivity can be sustained over time, as this indicator is extremely important for assessing the sustainability of an agroecosystem, despite being It is crucial that it is connected to elements that enable equity, resilience, stability and sustainability.

An optimal index corresponding to 0.92 was obtained, as it appears that with the increase in productivity in the agroecosystem, the social cost of production decreased and there was a certain gain for society and the rest of the residents nearby due to the ease of purchasing and reselling the banana. According to [30, 67, 68], the sharing of this gain essentially benefits the agroecosystem, and can bring some benefits to consumers, such as fruit quality, price reduction, or directly, to the workers themselves, through better remuneration or reduced time. /work.

Based on the index obtained, it can be seen that it is in line with that described by [34, 65, 66], who describes that fruit crops, when irrigated in nature, as well as the use of technologies and comprehensive management such as: productivity, soil management, carrying out frequent analyzes of soil fertility and water quality, sizing of support capacity and mechanical operational precision, desirable results in the sustainability of the agroecosystem can be obtained.

Furthermore, failure to use fallow cultivation areas represents a loss of gains for the pharmaceutical industry, as they could be reused for planting other commercial crops during fallow, combined with the fact that monoculture cyclically depletes the same nutrients in the soil, actions which when combined would bring significant results in terms of physical and chemical preservation of the soil and revenue capture.

3.2.2. Economic confidence – E2

In this index, the average level of reliability of the agroecosystem was evaluated through the net result of production with the values invested, and in situations when the price of bananas is devalued by more than 15% and the prices of inputs rise in the same proportion [19]. The index was weighted as follows: 0 – 2 means that you do not trust, but do not see any other type of work; 0 – 4 defined as very insecure, 0 – 6 indicated as somewhat insecure; 0 – 8 means the situation is rarely unsafe; and 1 – expressing a very safe situation.

Reference [36, 65, 65].In the present research, a reliability level corresponding to 0.84 was found, expressing a very safe situation, based on this, the agroecosystem in terms of economic confidence, is stable looking at investment and return, a fact, supported by [37, 63], who states that the goal of economic confidence in an agroecosystem is to seek to maximize profits, or net revenue. Based on this indicator, the properties of sustainability, stability and autonomy are perceived, as the agroecosystem uses strategies to maintain a certain constancy of productivity in the face of interferences considered disturbing and that arise due to social economic fluctuations.

3.2.3. Marketing – E3

The sustainability of the agroecosystem is defined mainly by guaranteeing production and followed by marketing. In this context, the measurement of this indicator in the context of the TAFC situation was based on knowledge of its main distribution channels, where the weighting indices were based on following ranges: 0

means only the intermediate; 0.5 demonstrates the participation of the intermediary, and sold wholesale and open-air markets; and 1 indicates wholesale, industry or exports [24, 62].

Based on field research carried out through the application of a survey to the company's workers and the administrative body, it was noticeable that TAFC, in the scope of commercialization, falls into two main indices as presented in the previous paragraph, with 0.5 demonstrating the intermediary participation, and sold wholesale and open-air markets; and 1 indicates wholesale, industry or exports. This index was called stable, corresponding to 0.75, as this company makes its products available to several national intermediaries, where 35% corresponds to direct purchase from the company and 45% corresponds to the supply of bananas in local supermarkets and open-air markets and only 20 % are destined for export in the Republic of South Africa.

3.2.4. Phytosanitary occurrence – E4

This parameter is based on the number of occurrences, as banana production systems are based on monoculture, so health problems appear and can often become unsustainable, affecting different parts of the plant, through various diseases. most common, mainly yellow Sigatoka or the occurrence of the fungus Fusarium oxysporumf.sp. cubense, which can remain in the soil for more than twenty years [38, 58].

This indicator expresses the yellow Sigatoka phytosanitary occurrence index that is common in modern agroecosystems, as cited by [24, 57], having been measured through variables and values, where: 0 means that it does not occur; 0.5 defines that it sometimes occurs; 1 indicates that it always occurs.

Regarding this index, the indicator was considered in a stable state as it presented an index of 0.75, and based on the field research carried out, as it was possible to understand through the field evaluation and application of a questionnaire to workers and the person responsible for production in the field, where he responded that yellow Sigatoka rarely occurs.

3.2.5. Management and accounting – E5

The management and accounting tool describes managerial capacity through accounting information, planning, budget control, possible decision making, cost control and comparison of results [34, 59, 60], carried out through interviews with the management team. The weighting of its results was based on the variables, on a scale: 0 means no control; 0.4 indicates that it stores it in memory; 0.6 means you write it down in your notebook; 0.8 corresponds to archiving information and documents and 1 indicates that it carries out rural and accounting management. According to [24, 53, 54], the relationship function of this indicator is positive (+), since the greater the implementation of rural and accounting management in the agroecosystem, the greater the autonomy and capacity to take measures that are necessary, in order to become a competitive and sustainable Production Unit.

The E5 indicator indicates the state of sustainability between stable and excellent, with an index equal to 0.80, where this result comes from this agroecosystem archiving information and documents, as according to

Reference [20, 34, 55], plays an important role as it is a regency tool that allows, through information visualization and document archiving, enabling the history of the productive and financial situation of the UA, as well as analyzing the socio-economic sustainability capacity of the agroecosystem and obtaining budgetary control for decision-making in banana cultivation.

3.2.6. Synthetic sustainability index S³ of the economic dimension

Figure 3, the biogram, through the graphic image generated, illustrates the level of sustainable development of the economic dimension in which TAFC is in a state of stable sustainability, with an index corresponding to 0.71, this can be justified by the use of techniques and new technologies, as the indexes of the indicator variables, as illustrated in the biogram, are more expanded, thus demonstrating stable economic sustainability.

Despite having obtained a stable index, TAFC suffers from the constant change of its managers, as each of the departments has its own projects and priorities, which always requires a situation of dynamics and focus, however, it brings negative results to the sustainability of the agroecosystem, as projections are made followed by a few steps and then a change in the initial scope, in addition to not allowing a reliable record of the unit's socioeconomic growth since its implementation.

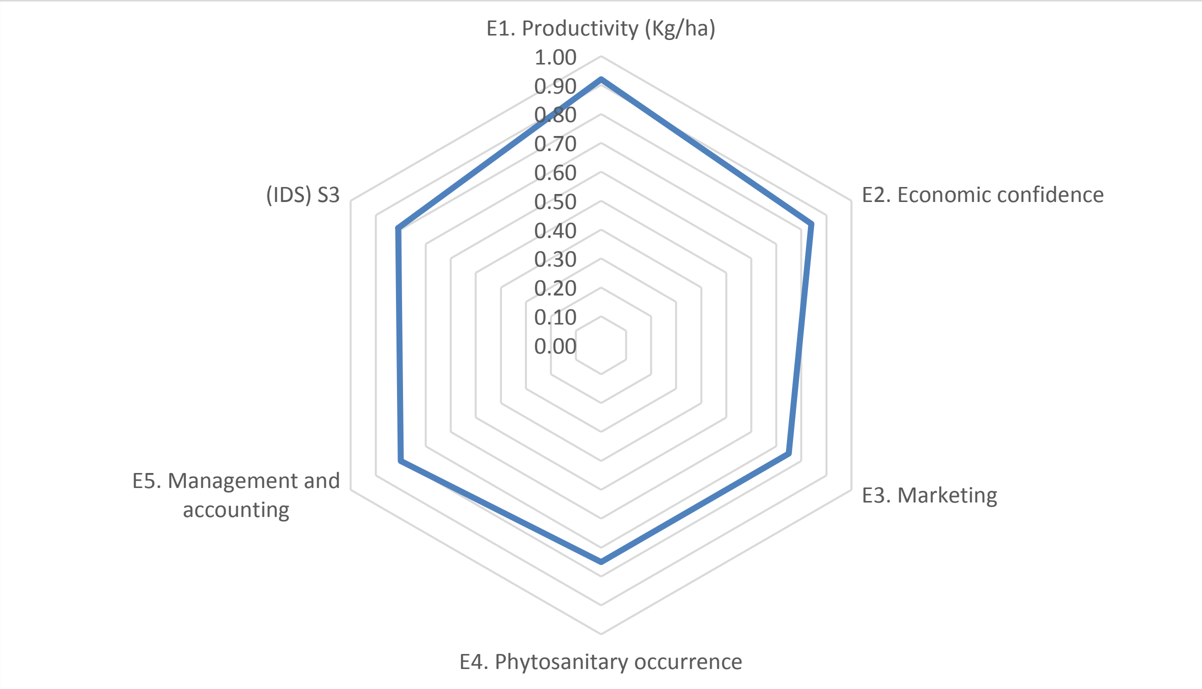

Figure 3: Biogram of the synthetic sustainability index S³ of the economic dimension

3.3. Social dimension and its indicators

The reality of social well-being in the agroecosystem, linked to social equity, satisfaction of people's needs, improvement of life and social justice, through indicators related to employment, health and education, was measured based on five sustainability indicators defined through of the relationship function, the maximum and minimum value and the arithmetic mean are processed, which generates the synthetic sustainability index S^3 Reference [10].

3.3.1. Direct employment – S1

The determination of this index was based on the quantification and calculation of the number of workers per hectare, in this regard TAFC has 122 men and 111 women, totaling 233 jobs, these are distributed in 11 – in maintenance services, 51 – in packaging services, 21 - in harvesting, 110 - in the farm, - 16 in irrigation, 22 security guards. To determine the index, the distribution of workers presented previously was applied, considering workers directly linked to the farm management system in production, such as farm, harvesting and irrigation workers, corresponding to 63% of the universe of farm workers. pharma, where the employability index was quantified in an excellent state with 0.92 direct jobs per hectare. [24, 53] reports that The relationship function of this indicator is positive (+), because the higher the rate of direct jobs generated per hectare, the greater the possibility of a certain equity in socio-environmental benefits.

3.3.2. Worker's place of origin – S2

This indicator was calculated based on the percentage of total workers coming from the town of Chivongoene, other locations and other points outside the district of Guijá, and through the variables of the worker's origin. In this context, of the 233 total workers, 95% are local and the remaining 5% come from other parts of the country and the neighboring Republic of South Africa. The relationship function of this indicator is positive (+), as it has increased in value the locality of Chivongoene, because the greater the percentage of workers from the locality of Chivongoene and the District of Guijá, the more equitable the distribution of productivity benefits will be, such as local socioeconomic improvement, combating poverty through job creation throughout of time, aiming for local sustainability. The S2 indicator calculated the stable sustainability status, with an index of 0.95, considering a good result, as of all the company's employees, only 5% do not come from the District of Guijá.

According to Reis [24, 51], local employment is seen as the use of human resources, avoiding rural exodus and allowing people's satisfaction and family social well-being. Looking at the index obtained in this research, it is clear that there is a contribution to reducing the local unemployment rate and increasing the local economy, as according to [23, 52], job creation is connected to income local, helping people to remain in their place of origin, together with their family, without having to be away for long periods.

3.3.3. Precariousness of work – S3

Based on the assessment of the degree of precarious labor relations in the TAFC agroecosystem, the work precariousness index was determined through the socio-environmental and economic conditions developed in the agroecosystem. Its assessment was based on the job insecurity variables described by [24, 50], which describe the employee's relationship with their workplace, as Mozambican labor law legislation provides for three types of rural employment contract, Being: permanent, temporary and seasonal (short term).

Based on these intervals, it was noticed that of the 233 workers existing in the agroecosystem, all have fixed contracts, which corresponds to an index equal to 1, considering a stable employment relationship within the agroecosystem. Allied to this, according to [39, 49], the assessment of the precariousness of work, contributes to evaluating the current conditions of forms of work relationships, as it has a great contribution to the construction of an equitable society that fundamentally permeates the fight to inequality in labor relations, and thus ensures the reduction of poverty and the strengthening of worker satisfaction, autonomy, and stability, one of the main challenges of local sustainable development.

3.3.4. Use of personal protective equipment – S4

This indicator was measured based on the assessment of the level of use of personal protective equipment (PPE) by workers, based on what was described by [40, 48], where he states that PPE must be used by people who perform tasks or pass through the field during or after the application of agrochemicals and by those who manipulate machinery or work tools that constitute a safety hazard in the work environment.

To search for information regarding the use of PPE at TAFC, field interviews were carried out with workers, based on the variables that address the receipt of PPE and the monitoring of the use of this equipment by workers. The relationship function of this indicator is positive (+), since the higher the weighted value, the greater the safety and health conditions of the worker, which will promote a higher well-being index, in this regard the index corresponding to this indicator measured the optimal state 1, as TAFC workers receive and make good use of PPE, thus guaranteeing the protection of life, promoting the safety, health and well-being of workers when carrying out unhealthy tasks, as, for [41, 47], the PPE recommended for banana cultivation are: masks suitable for agrochemical manipulation, glasses, waterproof gloves, waterproof wide-brimmed hat, waterproof boots, overalls with sleeves long coats and a waterproof apron.

3.3.5. Education – S5

The assessment of the degree of training or level of education was based on the calculation of the percentage of workers who do not know how to read and write in the Production Unit, since, according to [42], the level of training school of those responsible for agroecosystems and workers connects with safety and quality in the development of tasks that promote autonomy and resilience in the face of environmental and socioeconomic anomalies, such as: crop management, operation and calibration of equipment; use of PPE; carrying out rural accounting, among others.

According to [10], the relationship function of this indicator is negative (–): the higher the percentage of people who cannot read and write, the lower the prospect of “interaction between sociocultural and environmental systems” of the agroecosystem. In this regard, based on the percentage of individuals who cannot read or write in the present agroecosystem, the S5 indicator calculated the critical state, with an index of 0.38, of sustainability. This result makes us realize that within the agroecosystem, there is low empowerment of workers over their rights, in terms of understanding the need for job security. Although [24], in his work, highlights that the percentage of low education (not knowing how to read and write) of agroecosystem workers does not mean that they lose knowledge since there is an immeasurable wealth of popular and traditional knowledge among the different groups of rural workers, however, the critical thing can be seen regarding the use of technologies and management of inputs, such as pesticides, there are gaps in the qualification of the vast majority of workers in the Production Units.

In the same context, the same author highlights in his study that the education of professionals in the banana production agroecosystem is essential, since both in the area of production and in administration it contributes to environmental, economic, social and political-institutional management, boosting sustainability in the agroecosystem. [43, 46] maintain that to guarantee the sustainability of the agroecosystem in general, it depends mainly on the skill, experience and educational level of the producer.

Following the same logic, [44, 45] adds that to develop desirable and responsible programs on the use of pesticides, it is necessary to include some literacy programs and training of workers in the management of agrochemicals, technical assistance, the use of protective equipment, the necessary structure for monitoring, the forms of participation of social actors in the decision-making process.

3.3.6. Synthetic S^3 sustainability index for the social dimension

Figure 4, the Biogram below, through the graphic image generated demonstrates the level of sustainable development, social dimension, of TAFC, presents a critical sustainability index, index 0.22, regarding the level of education – knowing how to read and write, but the indices of the rest present an optimal sustainability index with indices in the range of 0.8 to 1.0.

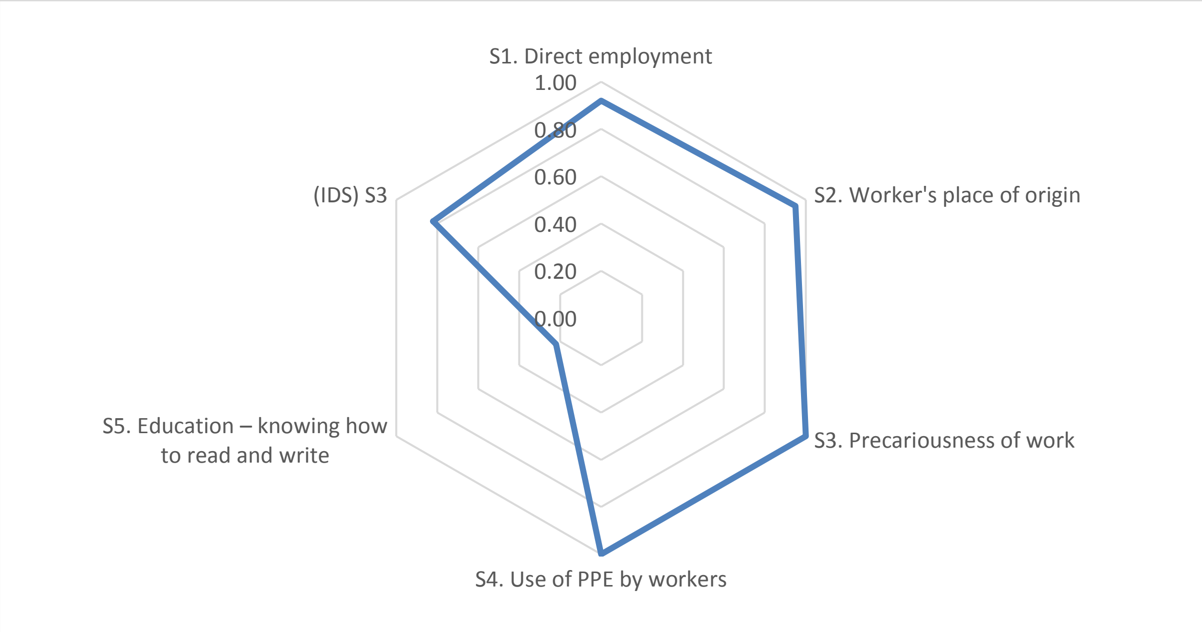

Figure 4: Biogram of the synthetic sustainability index S^3 of the social dimension

3.4. General Sustainable Development Indexes S^3

In Figure 5, the sustainability indices of the agroecosystem, the dimensions and representative indicators (components of the dimensions, general index) and the sustainable development index IDS S³ (synthetic) were systematized.

From the analysis of this Biogram, it can be highlighted that in the different dimensions evaluated, multidimensional sustainability indices were obtained that range from stable to excellent, however for the dimensions that present a critical level of sustainability, intervention is necessary TAFC continues to search for sustainable processes, correcting flaws while achieving desirable sustainability. Therefore, it is necessary to identify, select and disseminate possible technologies that allow development limitations to be overcome; it can also lead to new research actions or specific policies that promote local sustainable development.

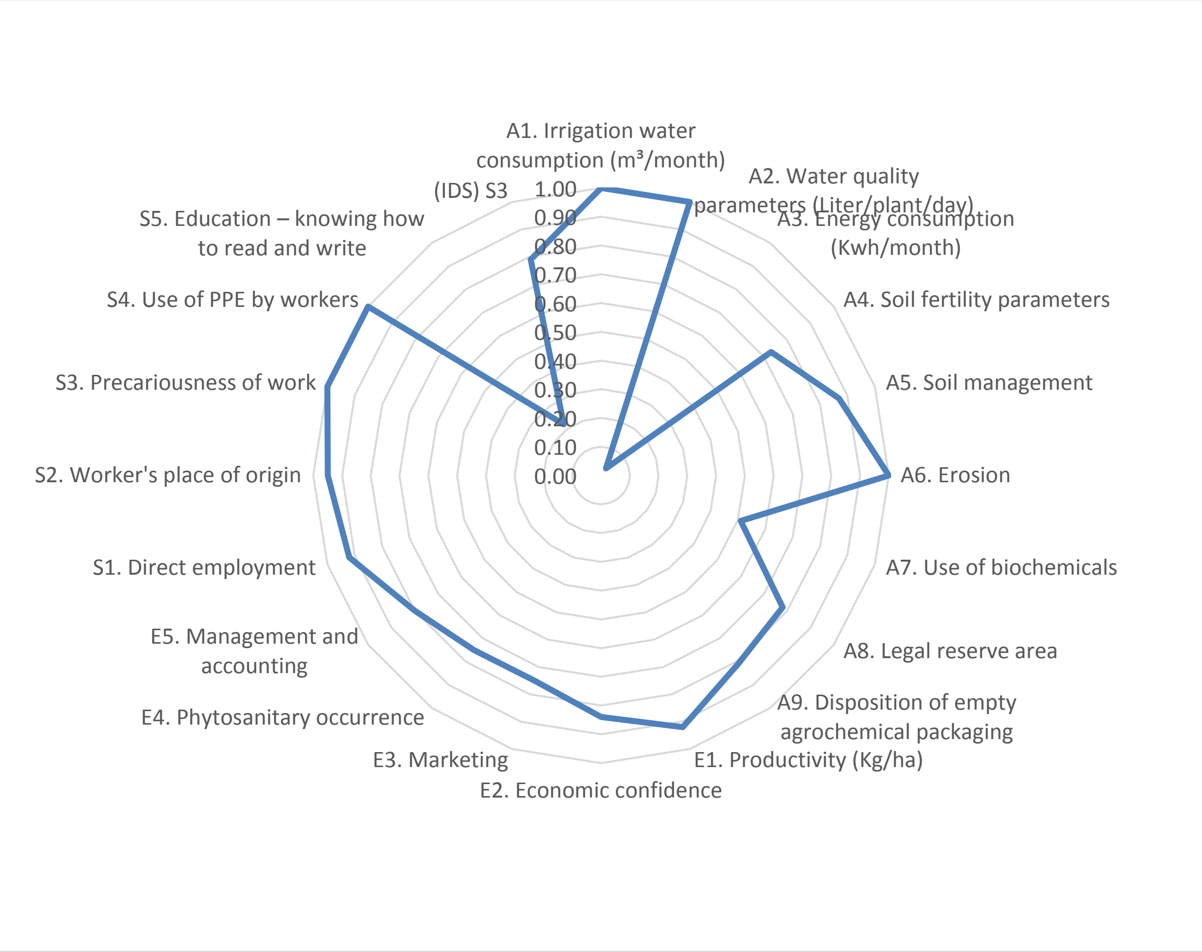

Figure 5: Comparative Biogram, of the synthetic index S³, of TAFC sustainability

4. Conclusion

After conducting this research at TAFC, a banana production company in the modernized system or irrigation and its derivatives technological levels related to the aspects included in the Sustainable Development (S³) indexes, through the evaluation of the environmental, economic and social dimension indexes, which corresponds to the evaluation of resilience, productivity and equity, respectively. It was noticeable that the agroecosystem is environmentally sustainable despite having presented an indicator in a critical state (energy consumption), as it is above the recommended, being 0.36 Kwh/day.ha.day and two indicators with a state (soil management and uses of agrochemicals) related to the agricultural practices applied, which violate some principles of sustainability.

As for the economic dimension, it also showed sustainable development indices (S3) that vary from stable to excellent, with this the agroecosystem contributes to the guarantee of its self-sustenance, as well as the leverage of the local and regional economy. The social dimension presented indices that vary from stable to excellent, with only a low index in the level of education, about knowing how to read and write, since most of the workers inserted in this agroecosystem are local residents who do not have a professional training, having a group that graduated only up to primary school. In short, TAFC has a stable sustainability index, as it presents resilient, productive practices with a level of equity. For the indices that presented a critical level, it is recommended to apply practices and policies that guarantee the maintenance or guarantee of the company's sustainability.

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