



PESTEL analysis with neutrosophic cognitive maps to determine the factors that affect rural sustainability. Case Study of the South-Eastern plain of the province of Pinar del Río.

C. Barrionuevo de la Rosa¹ . B. Cárdenas Bolaños¹, H. Cárdenas Echeverría¹, R. Cabezas Padilla¹, G. A. Sandoval Ruilova²

¹Universidad de Guayaquil, Fac. de Ciencias Administrativas, Guayaquil, Ecuador. Email: cesar.barrionuevod@ug.edu.ec; brenda.cardenasb@ug.edu.ec, hugo.cardenase@ug.edu.ec, roddy.cabezas@ug.edu.ec

²Gustavo Adolfo Sandoval Ruilova, Candidato Doctoral Universidad Politécnica de Madrid, España. Email: gustavoadolfo.sandoval.ruilova@alumnos.upm.es

Abstract. Neutrosophic cognitive maps and their application in decision-making have become an important subject for researchers and practitioners. Especially, PESTEL analysis based on neutrosophic cognitive maps is a useful method, which permits to analyse specific topics statically. In the present paper strategies for the external factors that contribute to the identification of agricultural contexts in the South-Eastern plain of the province of Pinar del Río, Cuba are studied based on PESTEL analysis and neutrosophic cognitive maps. Here, PEST analysis incorporates Ecological and Legal factors and their characteristics. This study aims to determine which factors affect the agricultural sustainability of the South - Eastern plain of the province of Pinar del Río. The main contribution of the present paper is that it was identified quantitatively the factors that affect the agricultural sustainability, they are, the technological, political and economic ones.

Keywords: PESTEL analysis, Neutrosophy theory, cognitive maps, agricultural sustainability.

1 Introduction

The term sustainable, lasting or sustainable development applies to socio-economic development. It was formalized for the first time in the so-called document Brundtland Report in 1987, as the result of the work of the World Commission on Environment and Development of the United Nations, created in the United Nations Assembly in 1983. This definition assumes the Principle of 3rd Rio Declaration of 1992, according the needs of the present without compromising the ability of future generations to meet their own needs.

The scope of the development conceptually sustainable is divided into three parts, viz., environmental, economic and social. The social aspect is defined as the relationship that exists among social welfare, environment and the economic bonanza.

Based on the aforementioned conceptualization, it is noteworthy that agricultural sustainability in Cuba, as a small island and as a developing state, presents a high degree of vulnerability to the impacts of global environmental problems. In particular climate change, which they are intensely reflected through ecological, environmental, legal and industrial factors of the key sectors of the economy, such as agriculture, tourism, construction, transport and fishing, substantially affecting their objective of achieving real sustainable development, see [1].

The South-Eastern plain of the province of Pinar del Río in Cuba has a livestock production, which is one of the most important agricultural branches, for its role in human nutrition. It is referred in [1] that the flat relief is favorable for agricultural sustainability since the climate in this area of study is favorable for the forage plants growth, which guarantees the feeding of livestock.

Similarly, other papers of the aforementioned author refer to the agricultural production in the Southern-East plains of the province of Pinar del Río. Aridity and other adverse factors affect this territory, increasing the unfavourable effects on soils, and causing the accelerated loss of agro-productivity.

Some of these adverse effects are, the groundwater contamination because of saline wedges penetrations, the lower availability of water resources for irrigation due to the recurrence and extension of droughts, the loss of crops due to the appearance of pests and diseases, the decrease in yields due to the rise in temperature and the

losses due to the occurrence of extreme hydro-meteorological phenomena.

Moreover, let us note that Cuban agriculture is a source of significant direct and indirect revenues to the economy in terms of convertible currencies. These are products containing a recognized quality, which are exportable funds or essential attractions for the tourism and the domestic foreign exchange market.

Among the main products that contribute to the existence of sustainable agriculture in Cuba are, coffee, cocoa, citrus, sugar cane, rum and honey. All of them are affected by the impacts caused by climate change, in one way or another.

Based on the aforementioned elements and the analysis of the effects produced by the adverse factors that affect the sustainable agricultural development in the area of study, PESTEL analysis is applied.

The PESTEL analysis is a strategic analysis technique to determine the external environment that affects the following factors, namely, Political, Economic, Socio-cultural, Technological, Ecological and Legal. This analysis consists in determining the social forces that affect the microenvironment, i.e., to analyze all those general factors (nationals and internationals) that determine the framework in which the institutions of a given region act and that affect their specific environment: sector, market, customers, competition, suppliers, among others.

PESTEL analysis, as it is reported in [2], is a technique for analyzing business that permits and determines the context in which it moves, in turn, enables the design of strategies to defend themselves, take advantage or adapt to anything that affects the sector or market. The categories contemplated by this analysis are the following:

- Political factors
- Economic factors
- Socio-cultural factors
- Technological Factors
- Ecological factors
- Legislative factors

In this analysis, it is necessary to differentiate two levels of the environment; general and specific. In our case of study, the general environment refers to the external environment surrounding agricultural sustainability in the South-Eastern plain of the province of Pinar del Río, from a generic perspective. This analysis is realized in two ways. Firstly, the macroeconomic figures of the environment are detailed, as well as the evolution of the agricultural sector, to put it in a context that serves as a starting point, and secondly, the sector has been analyzed using the PESTEL model.

The analysis with the PESTEL model, according to [3], has gained ground in the literature in recent years. The aforementioned author reports that the term PESTEL was used for the first time by the authors Johnson and Scholes in their book "Exploring Corporate Strategy", in the sixth edition of the year 2002, without claiming the invention of the acronym PESTEL. For our case of study, the PESTEL model integrates the factors shown in Figure 1.

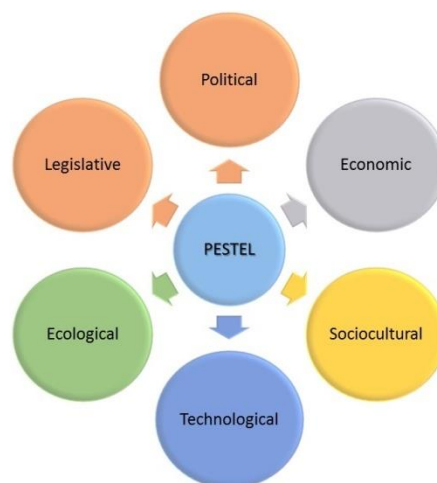


Figure 1. Factors that integrate PESTEL analysis and which affect the agricultural sustainability of the South-Eastern plain of the province of Pinar del Río.

A group of environmental factors, according to [4], using the PESTEL model and specified in Figure 1, are determined to identify the variables that have major incidence on the agricultural sustainability of the South-Eastern of the province of Pinar del Río.

Neutrosophy theory was proposed by Florentin Smarandache, for the treatment of neutralities. It generalizes crisp and fuzzy set theories, among others, introducing for the first time new concepts like neutrosophic sets and

neutrosophic logic [5].

Neutrosophic PESTEL analysis, which combines PESTEL analysis with Neutrosophic Cognitive Maps has been previously applied by other authors, see [6] where it was used to determine the factors that affect Food Industry. However, the problem we study in this research is particularly complex, because these six aspects are interrelated each other, in such a way that does not make sense to study only one of them independently of the other ones, and all the population is concerned.

Therefore, our main motivation is to propose strategies to solve this complex problem, which is a universal one. Additionally, we intend to demonstrate that neutrosophic PESTEL can be applied to solve problems of such magnitude. These are our aims to write this paper.

Neutrosophy is a useful theory that is increasing the number of its applications in many fields. In this case, the inclusion of this theory enriches the possibilities of PESTEL analysis, mainly because of two issues, firstly, the addition of the notion of indeterminacy and secondly the possibility to calculate using linguistic terms.

In the present study, PESTEL analysis using neutrosophic cognitive maps facilitates greater interpretability of the obtained results and contributes to the correlation between the characteristics of the factors of study. The analysis of the characteristics of each factor in PESTEL model eases to obtain the most important of them that influences in a greater agricultural sustainability of the South-Eastern plain of the province of Pinar del Río.

Furthermore, neutrosophy theory has significantly enhance crisp techniques, tools and methods. For instance, it has been successfully used in conjoint with methods like TOPSIS, VIKOR, ANP and DEMATEL, see [7-9].

The present paper is divided as follows, Section 2 of Materials and Methods summarizes the basic concepts necessities to achieve the solution of this problem. Section 3 of Results exposes the application of Neutrosophic PESTEL in the solution of the case of agricultural sustainability in the Province of Pinar del Río, Cuba. Finally, conclusions are drawn.

2 Materials and methods

In the present study, PESTEL analysis with neutrosophic cognitive maps are applied to determine the factors that affect the agricultural sustainability of the South-Eastern plain of the province of Pinar del Río. This is based on a descriptive methodology with a quantitative method. The result was achieved by using the descriptive methodology, which demonstrates that it is feasible to define the characteristics of the factors that intervene in the PESTEL model related to agricultural sustainability of the South-Eastern plain of the province of Pinar del Río, Cuba.

Firstly, let us formally expose the original definition of neutrosophic logic as it is shown in [10].

Definition 1. Let $N = \{(T, I, F): T, I, F \in [0,1]\}$ be a *neutrosophic set of evaluation*. $v: P \rightarrow N$ is a mapping of a group of propositional formulas into N , i.e., each sentence $p \in P$ is associated to a value in N , as it is exposed in the Equation 1, meaning that p is $T\%$ true, $I\%$ indeterminate and $F\%$ false.

$$v(p) = (T, I, F) \quad (1)$$

Hence, the neutrosophic logic is a generalization of fuzzy logic, based on the concept of neutrosophy according to [5, 11].

Definition 2. (See [12-13]) Let K be the ring of real numbers. The ring generated by $K \cup I$ is called a *neutrosophic ring* if it involves the indeterminacy factor in it, where I satisfies $I^2 = I$, $I+I = 2I$ and in general, $I+I+\dots+I = nI$, if $k \in K$, then $k.I = kI$, $0I = 0$. The neutrosophic ring is denoted by $K(I)$, which is generated by $K \cup I$, i.e., $K(I) = \langle K \cup I \rangle$, where $\langle K \cup I \rangle$ denotes the ring generated by K and I .

Definition 3. A *neutrosophic matrix* is a matrix $A = [a_{ij}]_{ij}$ $i = 1, 2, \dots, m$ and $j = 1, 2, \dots, n$; $m, n \geq 1$, such that each $a_{ij} \in K(I)$, where $K(I)$ is a neutrosophic ring, see [14].

Let us observe that an element of the matrix can have the form $a+bI$, where a and b are real numbers, whereas I is the indeterminacy factor. The usual operations of neutrosophic matrices can be extended from the classical matrix operations.

$$\text{For example, } \begin{pmatrix} -1 & I & 5I \\ I & 4 & 7 \end{pmatrix} \begin{pmatrix} I & 9I & 6 \\ 0 & I & 0 \\ -4 & 7 & 5 \end{pmatrix} = \begin{pmatrix} -21I & 27I & -6 + 25I \\ -28 + I & 49 + 13I & 35 + 6I \end{pmatrix}.$$

Additionally, a *neutrosophic graph* is a graph that has at least one indeterminate edge or one indeterminate node [15]. The *neutrosophic adjacency matrix* is an extension of the adjacency matrix in classical graph theory. $a_{ij} = 0$ means nodes i and j are not connected, $a_{ij} = 1$ means that these nodes are connected and $a_{ij} = I$ means the connection is indeterminate (unknown if it is or if not). Fuzzy set theory does not use such notions.

On the other hand, if the indetermination is introduced in a cognitive map as it is referred in [16], then this cognitive map is called a *neutrosophic cognitive map*, which is especially useful in the representation of causal knowledge [5, 17]. It is formally defined in Definition 4.

Definition 4. A *Neutrosophic Cognitive Map* (NCM) is a neutrosophic directed graph with concepts like policies, events, among others, as nodes and causalities or indeterminates as edges. It represents the causal relationship between concepts.

Neutrosophic Cognitive Maps are used in this paper, according to the proposed objective to include an indeterminate framework in the PESTEL analysis. The proposed framework is shown in Figure 2.

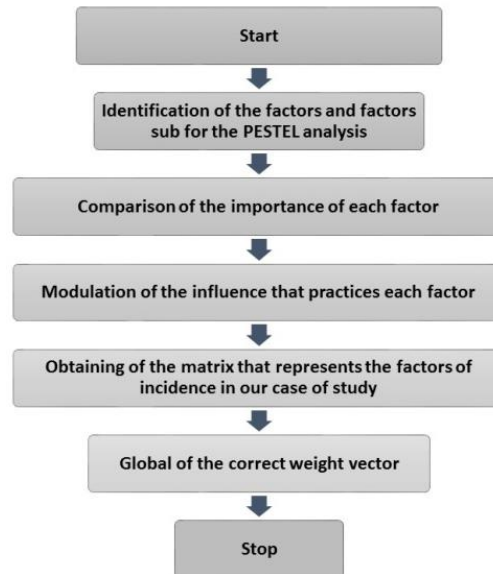


Figure 2. Framework to obtain the characteristics analyzed in each factor of the PESTEL model based on neutrosophic cognitive maps.

Neutrosophic cognitive maps are a generalization of fuzzy cognitive maps. Fuzzy cognitive maps are introduced by Axelrod, see [18], where nodes represent concepts or variables in a particular area of study and arcs indicate either positive or negative influences, and which are considered like causal relationships. They have been applied in various areas, especially in supporting decision making and in the analysis of complex systems as it is referred in [19]. Static analysis in a cognitive neutrosophic map focuses on the selection of the most important concepts, characteristics or factors in the modeled system [20].

The framework proposed in Figure 2 guides the process to obtain the characteristics of each analyzed factor, for agricultural sustainability in the South-Eastern plain of the province of Pinar del Río, with the PESTEL model. Integrated structure factors corresponding to an analysis of PESTEL and characteristics are modeled using neutrosophic cognitive maps, which contributes to obtain quantitative analysis of the characteristics that correspond to factor analysis.

The measures described below are used in the proposed model, they are based on the absolute values of the adjacency matrix [21]:

- Outdegree (v_i) is the sum of the row elements in the neutrosophic adjacency matrix. It reflects the strength of the outgoing relationships (c_{ij}) of the variable.

$$od(v_i) = \sum_{j=1}^n c_{ij} \quad (2)$$

- Indegree (v_i) is the sum of the column elements. It reflects the strength of relations (c_{ij}) outgoing from the variable.

$$id(v_i) = \sum_{j=1}^n c_{ji} \quad (3)$$

- Total centrality (total degree $td(v_i)$), is the sum of the indegree and the outdegree of the variable.

$$td(v_i) = od(v_i) + id(v_i) \quad (4)$$

The static analysis is applied using the adjacency matrix, taking into consideration the absolute value of the weights [20]. Static analysis in Neutrosophic Cognitive Maps (NCM), see [22], initially contains the neutrosophic number of the form $(a + bI)$, where $I =$ indetermination [23]. It requires a process of de-neutrosophication as proposed in [21] by Salmeron and Smarandache, where $I \in [0, 1]$ and it is replaced by their values maximum and minimum.

Finally, we work with the average of the extreme values, which is calculated using Equation 5, which is useful to obtain a single value as it is referred in [24]. This value contributes to the identification of the characteristics to be attended, according to the factors obtained with the PESTEL model, for our case study.

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \quad (5)$$

Then,

$$A > B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2} \quad (6)$$

3 Results

Figure 3 shows the factors and characteristics of the PESTEL model obtained for the analysis of agricultural sustainability in the South-Eastern plain of the province of Pinar del Río.

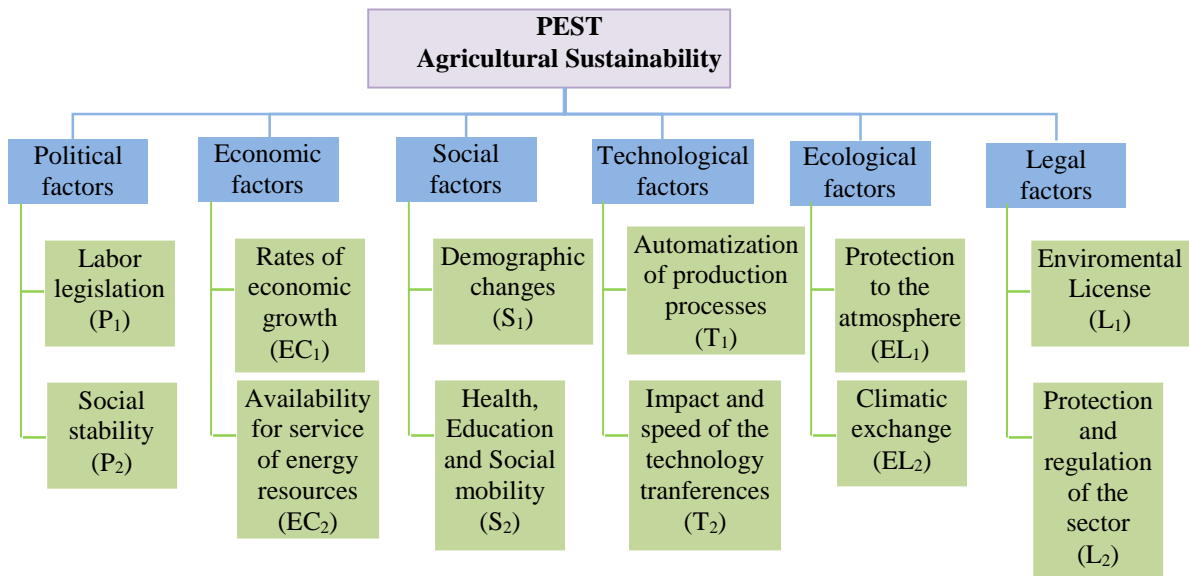


Figure 3. PESTEL hierarchical model for the analysis of Agricultural Sustainability in the South-Eastern Plain of Pinar del Río.

After obtaining the characteristics corresponding to the PESTEL model factors, we analyzed them keeping in mind that the PESTEL model is a strategic analysis technique to define the context of a determined area about the analysis of external factors, as it is referred in [25]. It is noteworthy that the PESTEL analysis incorporates the ecological and legal factors into the PEST analysis so that in the present investigation a PEST analysis was previously applied. Thus, the factors analyzed by using the PEST technique according to [26] are the following:

- **Political factors:** The first element of PEST Analysis is that we must make a study of political factors. In this sense, for our case of study, the political factors to evaluate are related to the impact of any political or legislative change that may affect agricultural sustainability in the South-Eastern plain of the province of Pinar del Río.
- **Economic factors:** Political factors do not operate independently, and public policy decisions have economic implications. All companies are affected by economic factors of national, international or global order. Behavioural, purchasing power is related to the stage of boom, recession, stagnation or recovery throughout which an economy growth. Economic factors affect the purchasing power of resources necessary for agricultural sustainability and the cost of capital for the company responsible for maintaining agricultural sustainability.
- **Social factors:** Agricultural sustainability focuses on the forces that act in the society and affect attitudes, interests and opinions of those who are influenced by decision-making. In reference [27] it is assured that social factors vary and include aspects as diverse as demography changes.
- **Technological factor:** it is another one of the factors to be taken into account, since technology is a driving force that contributes to an improvement in quality, it reduces entrance barriers.

After factors of the macro environment were defined with the aid of PEST technique, we defined the external factors that affect the agricultural sustainability in the South-Eastern plain, again by using the PESTEL model. Factors that are obtained with the purpose of defining this environment to measure the agricultural sustainability of this region and discussed according to [18], are the following:

1. **Ecological factors**
2. **Legal factors**

In the present study, the analyzed ecological factors correspond to the characteristics related to the protection of the environment and climate change. On the other hand, and with regard to legal factors, the characteristics

related to environmental licenses and the protection and regulation of the agricultural sector in the study area are analyzed.

In [28] it is pointed out that the obtained results with the PEST and PESTEL analysis, in particular, for each characteristic representing the factors under study, are presented in form of linguistic terms, therefore, in order to obtain a greater interpretability, a linguistic treatment is necessary to be able to quantify them. For this reason, in the present study, neutrosophic cognitive maps are used, as a tool for modeling the characteristics that are related to the factors that affect the agricultural development of this region.

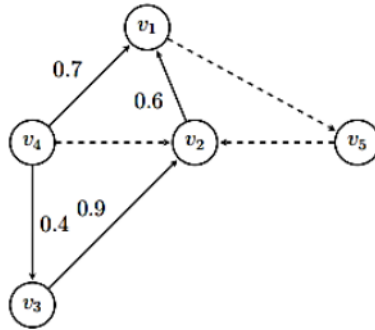


Figure4. Neutrosophic cognitive map. Source: [29]

Essentially, to perform static analysis on a NCM should follow the steps shown in Figure 5.

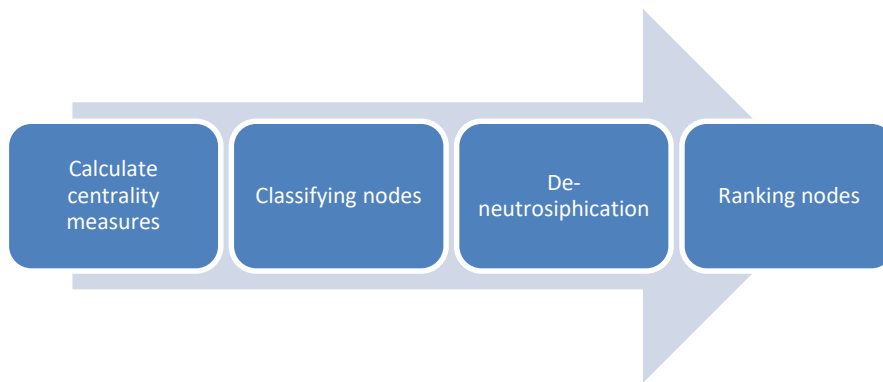


Figure 5. Steps to follow for static analysis in a neutrosophical cognitive map. Source: [29]

For the evaluation of the PESTEL factors with a neutrosophic cognitive map, the factors obtained with the PESTEL technique and the characteristics related to each factor that was represented in a hierarchical way in Figure 3 are taken into account. The MCN, for our case study, is developed through the capture of knowledge. The neutrosophic adjacency matrix generated is shown in Table 1.

	P ₁	P ₂	EC ₁	EC ₂	S ₁	S ₂	T ₁	T ₂	EL ₁	EL ₂	L ₁	L ₂
P ₁	0	0	0	-0.3	0	0	0	0	0	0	0	0
P ₂	0	0	0	0	0	0	0.25	0	0	0	0	0
EC ₁	0	0	0	0	0	0	0	0	0	0	0	0
EC ₂	0	0	0	0	0	0	0	0.3	0	0	0	0
S ₁	0.4	I	0	0	0	0	0	0	0	0	0	0
S ₂	0	0	0	0	0	0	0	0	0	0	0	0
T ₁	0	0	0	0	0	0	0	0	0	0	0	0
T ₂	0	0	0	0.35	0	0	0	0	0	0	0	0
EL ₁	0	0	0	0	0	0	0	0	0.25	0	0	0
EL ₂	0	0	0	0	0	0	0	0	0	0	0	0
L ₁	0	0	0	0	0	0	0	0	0	0.30	0	0
L ₂	0	0	0	0	0	0	0	0	0	0	0	0.20

Table 1. Neutrosophic adjacency matrix.

The measures of centrality are calculated using the Outdegree measures and Indegree, using Equations 2 and 3, the results are shown in Table 2.

Node	Id	Od
P ₁	0.4	0.3
P ₂	I	0.25
EC ₁	0	0.2
EC ₂	1.05	0.3
S ₁	I	0.7 + I
S ₂	0	I
T ₁	0.55	0.2
T ₂	0.3	0.35
EL ₁	0.25	0
EL ₂	0.30	0
L ₁	0	0.30
L ₂	0	0.20

Table 2. Measures of centrality, outdegree, indegree.

Once the measures of centrality were calculated, the nodes of the neutrosophic cognitive map were classified. This classification is shown in Table 3.

	Node transmitter	Receiving node	Ordinary
P ₁			X
P ₂			X
EC ₁			X
EC ₂	X		
S ₁			X
S ₂	X		
T ₁			X
T ₂			X
EL ₁			X
EL ₂			X
L ₁			X
L ₂			X

Table 3. Classification of the nodes.

According to the results shown in Table 3, E2 and S2 are receiving nodes. The rest of them are ordinary.

The total centrality (total degree $td(v_i)$), is calculated using Equation 4, the results for our case of study are shown in Table 4.

	td
P ₁	0.7
P ₂	0.25 + I
EC ₁	0.2
EC ₂	1.35
S ₁	0.7 + 2I
S ₂	I
T ₁	0.75
T ₂	0.65
EL ₁	0.25

EL ₂	0.30
L ₁	0.30
L ₂	0.20

Table 4. Total, centrality.

Next, the process of des-neutrosophication is applied as it is referred by Salmeron and Smarandache in [30]. $I \in [0,1]$ is replaced by values maximum and minimum. The Interval values are displayed in Table 5.

	td
P ₁	0.7
P ₂	[0.25, 1.25]
EC ₁	0.2
EC ₂	1.35
S ₁	[0.7, 2.7]
S ₂	[0, 1]
T ₁	0.75
T ₂	0.65
EL ₁	1.25
EL ₂	1.30
L ₁	1.30
L ₂	1.20

Table 5. Total, des - neutrosophication of the values of total centrality.

Based on Equation 5, the mean of the extreme values are obtained to analyze the characteristics to be attended according to the factors obtained with the PESTEL technique in the present study. The results are shown in Table 6.

We conclude the factors that address the sustainability of the agricultural sector in the province of Pinar del Rio are the technological, political and economic factors. The measurements of the central position of the obtained factors with the PESTEL technique and analyzed according to the use of the neutrosophic cognitive maps are shown in Figure 6.

Then, the priorities can be ordered as follows:

$$S_1 > EC_2 > EL_2 \sim L_1 > EL_1 > L_2 > P_2 \sim T_1 > P_1 > T_2 > S_2 > EC_1.$$

	Td
P ₁	0.7
P ₂	0.75
EC ₁	0.2
EC ₂	1.35
S ₁	1.7
S ₂	0.5
T ₁	0.75
T ₂	0.65
EL ₁	1.25
EL ₂	1.30
L ₁	1.30
L ₂	1.20

Table 6. Median of the extremes values.

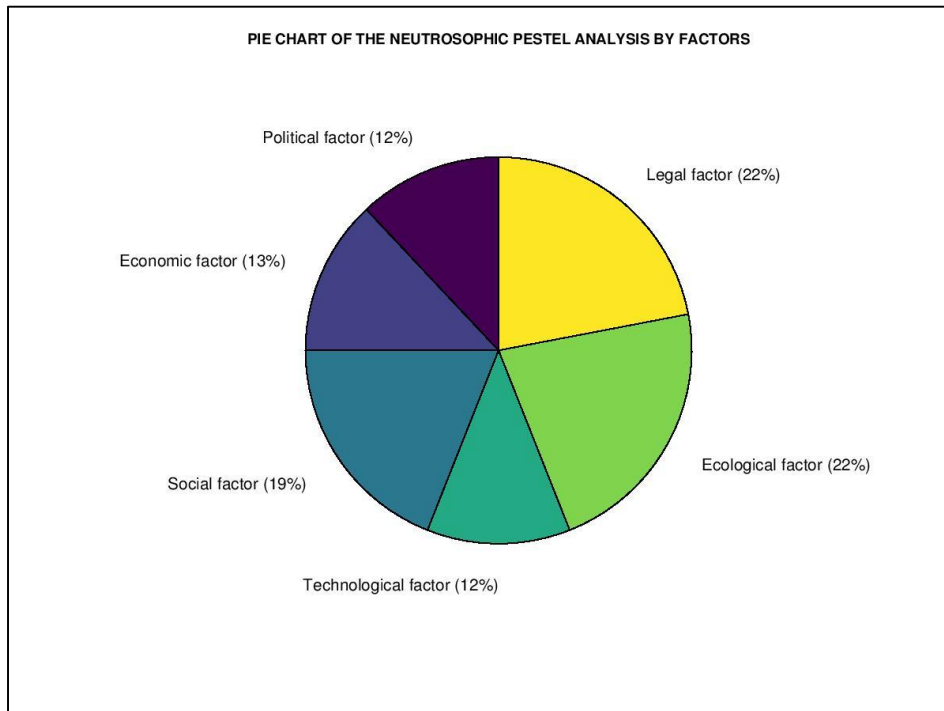


Figure 6. Values of central position for factors.

Conclusions

In the present study a characterization of the agricultural sustainability of the South - Eastern plain of the province of Pinar del Río, Cuba, is made. The PESTEL technique is used, contributing to environmental analysis, identifying key factors that have significant impact on the agricultural sector.

The most influential characteristics for the region and the agricultural sustainability of each identified factor are described.

The characteristics were modeled using neutrosophic cognitive maps, taking into account the interdependencies between the characteristics and the factors identified with the PESTEL technique, from which a quantitative analysis was applied, based on the static analysis provided by the use of neutrosophic cognitive maps.

It is shown that in order to achieve agricultural sustainability, technological, political and economic factors must be addressed. This result is the main contribution of this paper. Nevertheless, other contribution is that it was demonstrated that Neutrosophic PESTEL can be applied to the solution of complex problems like it is.

A future direction of this study is to assess the impact of the technological, political and economic measures that should be applied to reverse this negative situation.

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