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Research Paper

Comparative analysis of the sustainability level of the Chihuahua state in Mexico

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ABSTRACT
The importance of sustainability assessment lies in analyzing the pattern of the main economic, social and environmental variables, in order to carry out an adequate monitoring that is useful as a management tool in decision-making. Therefore, the objective of this study is to compare the level of sustainability between Chihuahua and other states during 2014 to identify the strategies applied by those that reach a higher level and that could be applied in Chihuahua. The methodology was applied to estimate the level of Sustainable Development in Territories, which allowed to identify that the states with the highest level of sustainability were Chiapas and Oaxaca due to the environmental programs they implemented. Of the eleven federative entities evaluated, Chihuahua ranked ninth, as a result of the low values in 85% of the indicators included in the methodology used in the evaluation.
KEYWORDS*: Sustainable development, indicators, biogram, strategies.*

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I. INTRODUCTION

The growing importance of sustainable development as a model to follow has initiated a debate on appropriate frameworks and instruments that will provide guidance for a change towards sustainability, as well as how to monitor such change, preferably in quantitative terms (Sala, Ciuffo & Nijkamp, 2015). Thus, sustainability assessment has the difficult task of capturing, measuring, and suggesting solutions to a diverse set of issues affecting stakeholders with different values and spanning different spatial and temporal scales (Gasparatos, El-Haram & Horner, 2008).

In recent years, the issue of Sustainable Development has become increasingly important in Latin America due to various reasons, including irrational use of natural resources, discrimination, inequality, unemployment, lack of opportunities, increased pollution in urban areas, among others. For this reason, various efforts have been made to achieve new balances between the environment and human activities (Liu et al., 2016; Gudynas, 2009).

Decision-makers, whether at different levels of government, businesses or particular interest groups, can be broadly guided by instruments that clearly indicate whether their initiatives are moving towards a higher or lower level of sustainability (Paez, 2003; Daneshpour, 2015; Dobrovolskiiene & Tamosiuniene, 2015; Moroke, Schoeman & Schoeman, 2020). For this reason, the use of indicators to measure sustainability is becoming increasingly popular as tools to guide decision making at national, regional and local levels, to identify and measure changes and processes that guide and promote the scope of sustainability (Walz, 2000). In this way, the main challenge of sustainability consists of linking the different economic, social and environmental elements, through a social project that allows the development of economic activities within the capacity of local ecosystems while guaranteeing the well-being of future generations (Sepulveda, 2008; Pollesch & Dale, 2016).

Assessing progress towards sustainability at the local or regional level is still in progress, and therefore some countries have made more progress than others in this task. Within Latin America, there are incipient

developments in environmental sustainability indicators that are being produced by government environmental agencies (Quiroga, 2001). Most of the countries that are evaluating sustainable development indicators use almost automatically the Pressure-State-Response framework recommended by the Organization for Economic Cooperation and Development (Pastor, Ramos & Santa Maria, 2016; Sunyer & Peña, 2008). Initiatives in Latin America have been undertaken in countries such as Costa Rica, Chile, Bolivia, Brazil, Barbados, Argentina, Colombia, and Venezuela. In Mexico, the National Institute of Statistics, Geography and Informatics (INEGI) and the National Institute of Ecology (INE) used a total of 113 indicators out of the 134 proposed by the Commission on Sustainable Development within the P-E-R model to evaluate the sustainability of this country (INEGI-INE, 2000).

Mexico has advanced in the fight against extreme poverty, according to data from the National Council for the Evaluation of Social Development Policy, from 11.3% of the national population in this situation in 2010, it was reduced to 9.5% in 2014 (CONEVAL, 2015)**.** However, it still faces great problems in the social dimension, since it is within the 25% of the countries with the highest levels of inequality in the world and is one of the two most unequal countries in the OECD (Esquivel, 2015). On the other hand, Mexico also faces problems related to the environmental dimension; according to data from the Ministry of Energy, the electrical energy consumption in 2014 was 2,014,788 kWh per capita (SENER, 2015). Added to this is the dramatic increase in deforestation, which produces losses of biodiversity and generally affects the health of the environment (Aguilar, Martinez & Arriaga, 2000).

Some government programs aimed at different sectors have failed because previous differential studies are not carried out to identify the most feasible strategies, according to the particular characteristics of the community or region they are targeting. Another important point is the lack of comparative studies of the level of sustainability between regions at different spatial scales, which would allow the analysis of the strategies that have been effective in positively impacting the indicators used.

Comparing the level of sustainability between regions allows for the identification of economic, social and environmental performance, and trends or scenarios that these regions might face. In this sense, the aim of this study is to compare the levels of sustainability between the states of Chihuahua, Baja California, Chiapas, Coahuila, Guanajuato, Morelos, Nuevo Leon, Oaxaca, Puebla, Quintana Roo and Sinaloa, in order to identify the programs or strategies that have been applied in the states with the highest level of sustainability and that could be applied in Chihuahua.

II. MATERIAL AND METHODS

The methodology for estimating the level of Sustainable Development in Territories, proposed by Sepulveda (2008) was applied. This technique allows the evaluation of sustainability at different spatial scales as well as producing results that can be visualized graphically because the methodology uses a biogram to represent the level of sustainability of the area under study. The methodology includes the following steps:

1. Selection of the unit of analysis. As part of the analysis and in the search to enrich the present study, one or more states from each economic zone of the country were selected. From the northern zone: Chihuahua and Coahuila, from the northwest: Baja California and Sinaloa, from the northeast: Nuevo León, from the center-west: Guanajuato, from the center east: Puebla and Morelos, from the south: Chiapas and Oaxaca. And finally, from the Yucatan Peninsula: Quintana Roo.
2. Analysis dimensions. Following the methodology, the economic, social, environmental and political-institutional dimensions are proposed, from which the latter was excluded due to the difficulty in obtaining solid and reliable indicators.
3. Temporary observations. The time frame of the study corresponds to the year 2014.
4. Indicators. Sepulveda (2002) proposed 15 indicators (5 for each dimension), of which 13 were selected (Table 1) due to the lack of information on the remaining two indicators.
5. Maximum and minimum levels. These correspond to the indicators with the highest and lowest values observed within the eleven states to be evaluated.
6. Indexes. In order to obtain all the indexes by state, first the relative one to each dimension was calculated, for this all the indicators were relativized according to the positive relation of the equation (1) or negative (2) that they keep. Later, the relativized values of the indicators of each dimension were averaged, according to the expression (3). The integrated index of sustainable development (S^3) was obtained from equation (4).

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

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

Where:
x is the corresponding indicator value for the unit of analysis.

$$S_D = \frac{1}{n_D} \sum_{i=1}^{n_D} I_i^D \qquad (3)$$

Where:
n_D is the total of indicators to be incorporated in each dimension.
I is an indicator of each dimension at a given time.

$$S^3 = \sum_{1}^{M} \left(\frac{\beta_D}{100}\right) S_D \qquad (4)$$

7. **Biograms.** It consists of a spider web diagram that represents the standardized values of the analyzed indicators, where the number of these determines the number of radii of the spider web. The diagrams shown in this study correspond to the states that reached the highest index in each dimension. In the economic dimension, Sinaloa (Fig.4), in the social dimension, Quintana Roo (Fig. 3), and in the environmental dimension, Chiapas (Fig. 1). The biogram for Chihuahua is also included (Fig. 2).

Table 1: Sustainable development indicators by dimension, proposed by Sepulveda (2008).

Economic	Social	Environmental
E1. GDP per cápita	S1. Mortality rate	A1. Reforested area
E2. Unemployment rate	S2. Poor househols	A2. Electricity consumption per capita
E3. Domestic debt	S3. Population density	A3. Emissions from mobile sources
E4. Inflation	S4. Public health expenditure (% GDP)	A4. Daily per capita waste generation
	S5. Public education expenditure (% GDP)	

III. RESULTS

To identify the values of the indicators proposed in the methodology, a documentary research was carried out in reports and sectorial publications of each state included in the study (INEGI, 2015; SENER, 2015; CFE, 2014; CONAPO, 2014; INECC, 2014 & INEGI, 2014). In this way, the maximum and minimum values indicated in step V were obtained, according to the methodology (Table 2).

In order to obtain the indexes by state, the corresponding equations (1), (2) and (3) were applied; so that, according to the integrated index of sustainable development (S^3), the states that achieved the highest integrated index of sustainability were Chiapas, Oaxaca and Sinaloa (Table 3). Of the eleven states included in the analysis, Chihuahua occupied the ninth place, with an Index of 0.39, sharing that site with Quintana Roo, placing it in the lowest levels of sustainability, only above Nuevo León, which in spite of having presented one of the highest economic indexes was at a disadvantage in the environmental dimension. As can be seen through this comparison, Chihuahua is below 0.25 points of Chiapas, so it is necessary to perform an analysis to identify the causes of the low values of the sustainable indicators included in the analysis, which placed Chihuahua in this position.

Although it is true that the level of sustainability is given by the average value of the indicators of the social, economic and environmental dimensions, it is necessary to analyze specifically those states that occupied the best Indexes in each of these dimensions. According to the biograms, Chiapas and Oaxaca achieved the highest rates in the environmental dimension. Sinaloa and Nuevo León in the economic dimension, and Quintana Roo and Chiapas in the social one (Fig. 1-4).

Table 2: Maximum and minimum values of each indicator.

Indicator	Maximum value (M)	Minimum value (m)
E1	237 151.00	56 139.00
E2	6.30	2.70
E3	9.00	1.30
E4	1.97	- 2.88
S1	7.10	3.60

S2	1 070.53	167.58
S3	383.53	14.83
S4	5.46	0.94
S5	1.15	0.18
A1	16 354.00	990.00
A2	1 744. 59	277.47
A3	7 592.00	2 500.00
A4	1.35	0.41

Table 3: Sustainability indexes by state.

State	S_D			S^3
	Economic	Social	Environmental	
Baja California	0.48	0.55	0.44	0.49
Coahuila	0.31	0.53	0.43	0.42
Chiapas	0.32	0.66	0.95	0.64
Chihuahua	0.25	0.50	0.41	0.39
Guanajuato	0.42	0.39	0.46	0.42
Morelos	0.47	0.43	0.71	0.54
Nuevo León	0.48	0.39	0.26	0.38
Oaxaca	0.40	0.66	0.77	0.61
Puebla	0.46	0.38	0.59	0.48
Quintana Roo	0.31	0.67	0.20	0.39
Sinaloa	0.66	0.57	0.43	0.55

Chiapas stood out in the environmental and social dimension, which contributed to it taking first place in the level of sustainability. However, it presented one of the lowest levels in the economic area. On the other hand, Sinaloa which occupied third place in the level of sustainability, was the state with the highest index of the economic dimension and, added to this, maintained an acceptable place in the social dimension, but presented a low index in the environmental. On the other hand, Quintana Roo stood out in a pronounced way in the social dimension but its low economic and social indicators did not allow it to stand out among the first places of sustainability.

On the other hand, the low level of sustainability presented by Chihuahua during 2014 is explained by the joint effect of the low values achieved in each of the sustainable dimensions. In the environmental area, it occupied the ninth place, in the social area the seventh place, and the economic area obtained the lowest place of the entities included in the comparative analysis. In the social area, it only stood out for the values obtained in the indicators S2 (poor households) and S3 (population density). However, in 85% of the total indicators of the methodology, it presented low values.

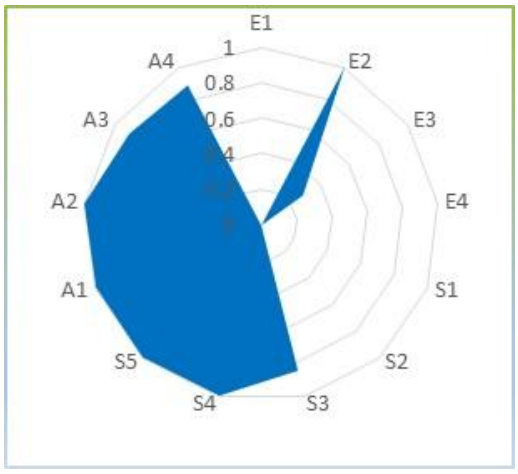

Figure 1. Biogram of the sustainability level of Chiapas

Figure 2. Biogram of the sustainability level of Chihuahua.

Figure 3. Biogram of the sustainability level of Quintana Roo.

Figure 4. Biogram of the sustainability level of Sinaloa.

Once the states with the highest indexes in each dimension were detected, a documentary investigation was carried out to identify the programs that these states have carried out and that could be implemented (under previous feasibility analysis) in Chihuahua, as possible strategies to increase their level of sustainability (Table 4). Chiapas and Oaxaca have various environmental programs that allowed these states to reach the highest indexes of this dimension, thus impacting the sustainability index obtained, in such a way that they compensated for their low economic index.

Table 4. Programs and strategies applied by the states with the highest rates in each dimension.

	Sinaloa	**Nuevo León**
Economic dimension	- "Sinaloa emprende" Program. - Foreign trade intelligence Program. - "Progresemos" co-financing Program. - PROEX- Export Promotion -RDS- Management, Logistics and Marketing of the Exploitable Offer - CAEX- Training program and attention to exports.	- Support to basic and applied research in strategic sectors. - Agreement between UANL and CONANZA. - "Hecho en Nuevo Leon" Program. - Basic Development Program for the competitiveness of micro enterprises in the trade, service and tourism sector of Nuevo León.
Social Dimension	**Quintana Roo**	**Chiapas**
	- "Adelante con la vivienda" Program - Basic Infrastructure Program. for the Attention of	- Agreement between IMSS and the Health Institute of Chiapas.

	Indigenous People (PIBAI). - Agricultural Day Laborers Assistance Program (PAJA). - Savings, Subsidy and Housing Credit Program "Tu Casa".	- Integrated and Sustainable Social Development Program for Social Cohesion in Priority Regions.
Environmental Dimension	**Chiapas**	**Oaxaca**
	- Environmental Logbook. - Environmental Protection Management Laboratory -Environmentally Responsible Education (ERA) - State Forest Fire Control Center (CECIF) - Fund for Sustainable Forest Development (FONDEF).	- Ecological Gaceta. -Urban Trees - Workshops, talks and advice given by the Secretariat of Environment, Energy and Sustainable Development.

IV. DISCUSSION AND CONCLUSION

Earlier, reference was made to the importance of comparing the level of sustainability between larger spatial scale regions. Considering this, the methodology used in this research allowed detecting both the states with the highest level of sustainability in general, and specifically the states that reached the highest indexes for each dimension. Subsequently, the programs and strategies carried out during 2014 by the states that reached the best levels of sustainability in general, as well as by each dimension, were identified. Specifically, Chihuahua did not stand out in any of the dimensions analyzed here, despite the proposals for action on climate change proposed by the state government.

The methodology used in this study has only been used on small spatial scales at the local level, so having used it to compare sustainability at the state level only offers an idea of the interaction between the economic, social and environmental dimensions between the states evaluated. However, the actions and programs carried out by the states that stood out in each of the sustainability dimensions, show evidence of the consistency of the results observed in the analysis.

It is necessary to develop new methodologies for measuring sustainability, which integrate criteria capable of differentiating the socioeconomic and environmental characteristics of Mexico and its various regions, in order to generate proposals to improve the interaction of economic, social and environmental variables and thus progress towards sustainability in a comprehensive and equitable manner, including each of the dimensions.

Some of the indicators included in the methodology used could favor the endogenous characteristics of the compared entities. Therefore, it is necessary to continue developing robust and comprehensive sustainability methodologies and indicators that allow for differentiated comparison studies between comparable regions.

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