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Quantitative Estimation of an Environmental Impact Factor as Technical Support for the Appropriation of Decisions

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Abstract: The environmental impact assessment is intrinsic activity for every long term project and its estimation is usually done qualitatively through an EIA Environmental Impact Assessment matrix. When there are several activities within a river basin, it is beneficial to estimate the indicator of environmental value or impact factor that occurs in an entire basin. However, the IVAFIC methodology allows quantitative estimation of this value through the IF (Impact Factor), using three attributes: duration, reversibility and nature which are associated with all environmental factors and anthropic activities, using the structural language of MATLAB and geographic information systems. This new indicator undoubtedly facilitates the decision-making of the environmental authority and the prioritization of the territorial ordering of watersheds.

Key words: Quantitative systematic model, Impact Facto (FI), basins or watersheds, decision-making, anthropic activities, environmental authority

INTRODUCTION

The presentation of river basin management and protection plans requires environmental information that is deficient in its quantified availability (Ongay *et al*., 2006). To overcome this limitation, it is necessary to use tools that allow to evaluate the available information organize it and generate it rapidly and with an acceptable degree of reliability.

Nowadays, there are technological tools that allow us to expand the cognitive horizon, in order to explore in a concrete way concepts that were distant from various studies. As an example of this, the Geographic Information Systems (GIS) as well as the structured programming configured with the language of MATLAB, among many others, undoubtedly make it possible to quantify, in this case, the environmental impact in a basin.

This research, in accordance with the above arguments, presents a systemic model for the quantitative evaluation of environmental impact at the level of a basin, called VATFIC (Phase 1). This phase is initially developed from the theoretical perspective, to explain the methodology, results and discussion of the findings, using as a case of study, the Garagoa River Basin (Colombia).

MATERIALS AND METHODS

Develop and description of IVAFIC Model (phase 1)

Conceptual framework: The VATFIC Model in its phase 1 is a systemic procedure of mathematical meta-heuristic type, based on a qualitative approach represented in an EIA (Environmental Impact Assessment) matrix, to quantify or value the impact produced by the anthropic effects in different environmental agents that represent the environmental scenario of a basin. This quantification includes the designation of three features such as durability, reversibility and nature which for the working scale, corresponding to a river basin are meaningful insofar as they reflect the given behavior (Pouey and Monroy, 2010).

Correlating this assessment to a specific unit area as it is for this case the municipality grouped in turn in provinces, it is interesting to determine an (IF) Impact Factor and a Corrected Impact Factor (CIF) which represents a numerical value which enables a simple and quick interpretation of the consequences produced by the action of an activity or a project to an environmental factor in a specific land area. Thus, through the implementation of a mathematical formula, it is possible to quantitatively identify the actions with the greatest impact in a river basin (Pouey *et al*., 1994).

The entire basis of estimation of the environmental impact caused by a project, stars from the matrix of Flores *et al*. (2010). Some previous contemporary works that quantify the environmental impact but not at a river basin level, correspond to contemplates various features and quantitatively evaluates them through a mathematical expression that concludes in what he calls importance of effect. As an application of this methodology is described

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Table 1: Impact classification

Definitions	Values (+/-)
Temporary-revesible	5
Permanent-reversible	9
TEmporary-irreversible	8
Permanent-irreversible	12

Table 2: Impact value to export on MATLAB

Impact descriptions	Colors	IF
Irreversible negative impact		-12
Positive permanent impact		9
Permanent negative impact		-9
Temporary positive impact		5
Temporary negative impact		-5
Mitigation impact measurement		5

in Mujica. Another research belongs to Morales G, in his doctoral thesis of the Federal University of Parana in Brazil. He in the same way, estimates the so-called impact importance in relation to the intensity, effect, extension, temporality, duration and reversibility. Pouey and Monroy (2016), already has estimated the value of the environmental impact at the basin level through the following expression which the base of the IVAFIC methodology of this research:

$$FI = 2D + R$$

Where:

FI = Impact Factor
D = Duration
R = Reversibility

The symbol of FI is given by the feature, nature. The impact factor will have a value within the following ranges.

It should be understood that the value set will be negative if the impact is negative or positive if the impact is positive. Once, the EIA (qualitative) matrix is elaborated, the assessment is carried out based on the features shown in the previous table of each of the impact factors associated with the activities and environmental factors of a basin (Table 1).

Once, this task is done, it is proposed to optimize the procedure by using the MATLAB mathematical calculation tool for which it is exported from the spreadsheet containing the EIA and which in turn has assigned a value of IF for each color according to Equation (Table 2).

IF (Impact Factor) program: The program is formed by a main core that refers to the main subroutine of calculation and in turn it must indicate the path where the files or database is located to analyze. To be able to display this initial screen it is necessary in the first place to have uploaded on MS Excel the three input-matrix information, which are:

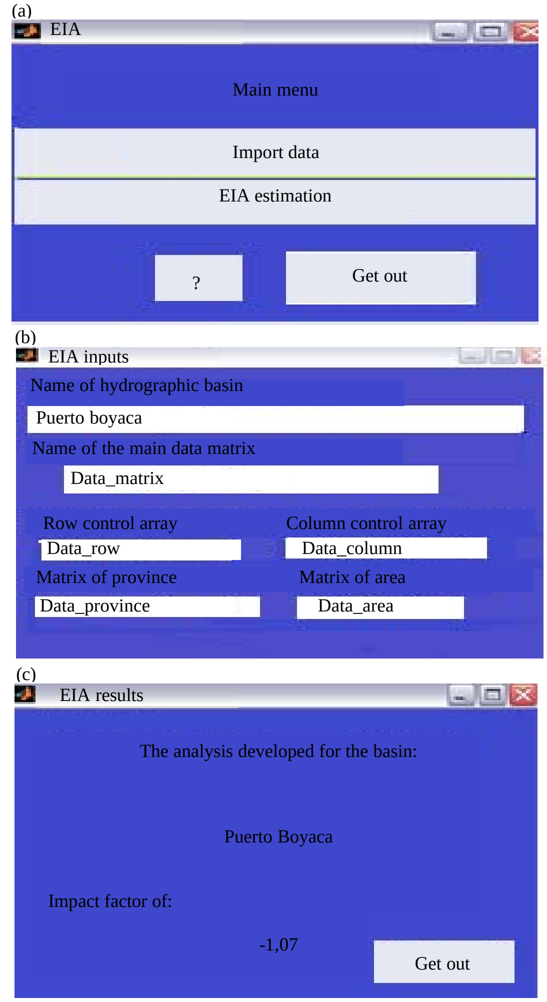

Fig. 1: Input on the program EIA

The polychromatic matrix (EIA); the matrix indicating the gaps between analysis factors. This array must be stored in an Excel file, in which will be shown the indexes of the cells where the subfactors that are involved in the analysis are grouped.

The indicator matrix between analysis activities. This array must be stored in an Excel. In which the indexes of the cells where the subactivities that are involved in the analysis are grouped will be displayed.

After storing the matrices in Excel and saved in their original format, the MATLAB program is initialized. Figure 1 shows the results of the impact factor. The path where the three arrays are located must be indicated in the "Path Browser" and in the command window write "eia_guil" as follows.

CIF; Corrected Impact Factor: However, it is possible to identify a correction factor corresponding to the area of application of the impact which we will call E as an extension factor. This factor was applied for the quantification of total activities or projects according to their effect on the global component or global environmental factor. The unit area of the municipality has been determined as a dimension of the development of biopolitics, bio-power and "good governance", topics that have been selected by Michel Foucault. In the same way, we can group the municipalities into a unit which given the magnitude of a basin is beneficial and no less important than the province, seen as a local entity with its own legal authority, determined by the grouping of municipalities and land division for the fulfillment of different governmental activities:

$$E = \left(\frac{\text{Province area}}{\text{Total basin area}}\right)$$

In any case the sum of all the values of E is equal to 1.0. From the above, we must:

$$EC = E \times \text{area}(\%)$$

Where the percentage area indicates the amount of portion of E that is effectively impacted by the province.

$$FIC = EC\left(\frac{FI + EC \times FI}{2}\right)$$

Where:

FIC = Corrected Impact Factor
EC = Run Extension factor
FI = Impact Factor

The value ranges for CIF, according to the above expression are: low: 0-5, low-medium: 5-8, medium: 8-9, medium-high: 9-11 and high: 11-12.

To obtain dexterity in the development of calculations for the CIF, an extension matrix EC for each province is elaborated which describes the area of affectation of an activity on an environmental factor. This matrix must be constructed in a spreadsheet that is subsequently exported to the MATLAB mathematical calculation tool, following the same procedure developed for calculating the FI.

GIS-IVAFIC interaction (phase 1): Currently, GIS geographic information systems have been positioned within the scope of engineering as a fundamental tool for the representation, measurement and projection of current and future contexts. Therefore, this research associates the quantitative interpretation given as IF and CIF to a graphic demonstration that in educational terms facilitates the interpretation of the results obtained and in turn, the relevant behaviors produced by the exercise developed.

This tool allows to exemplify, among others, maps that in this research have been called ISOFICS which carry the environmental impact assessment formulated in its phase 1 to the basic territorial unit or extension which in this research has been designated as the municipality.

RESULTS AND DISCUSSION

IVAFIC Model sensitivity analysis

Experimental design: Once the EIA, IF and CIF matrix has been calculated, a sensitivity analysis of the proposed model is performed for which several scenarios are recreated randomly, eliminating activities and factors and recalculating the different values of IF and CIF. A sensitivity analysis requires the recreation of several scenarios in the sense of being able to estimate tendencies, boundaries, maximums, minimums, etc. For the validation of this research, 220 scenarios were built, taking into account the different ranges of combinations between anthropic activities and environmental factors as scenarios.

Graphical display of the behavior of the IF and CIF (Impact Factor and Corrected Impact Factor): In response to the sensitivity analysis, the impact factor and its consequent component coding in its intrinsic matrix shows a graphical spectrum that represents the behavior of these indicators under the alteration or omission of some of components of this study. Figure 2 shows the spatial distribution of all combinations made between environmental factors and anthropogenic activities. A

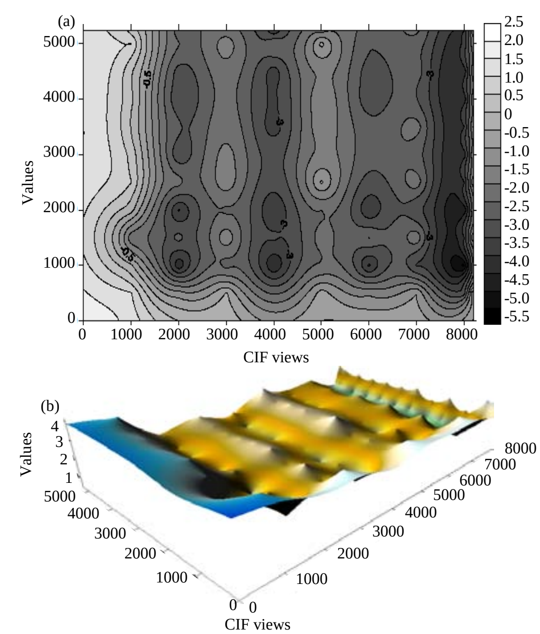

Fig. 2: 3D CIF view: a) Environmental factors and b) Anthropoenic activities

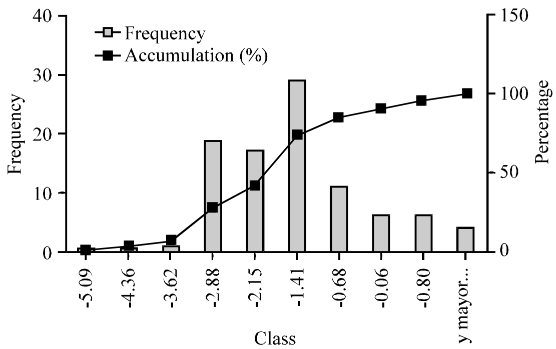

Fig. 3: Histogram IF and CIF

standardized tendency with peaks at the ends near the beginning of the field of the layout is seen in the diagram because of the lack of main components that should be incorporated in any environmental impact study. Likewise, a representation of multiple components does not necessarily lead to the best result and the final answer is subject to statistical interpretation as will be indicated in later researches.

Descriptive statistics of the results: Tukey, developed a procedure called EDA: Exploratory Data Analysis that represents an approach and not a set of techniques, it means, an activity or philosophy about how an analysis of the data must be carried out. They are among the various statistical tools.

Histogram IF and CIF: A common resource for representing data is a histogram. It consists of a horizontal scale for values of the data being represented by a vertical scale for frequencies and bars representing the frequency of each class of values (Ross, 2009). Figure 3 shows the frequency histroram of the environmental impact factor.

Setting the IF and CIF data to a probability density function: From the result obtained from the histogram shown in the previous figure, a distribution adjustment is made by the Chi-square and Kolmogorov-Smirnov hypothesis test. The purpose of hypothesis testing is to assess whether statements about the parameters of an assertion are true or not. In any test there are two types of hypotheses: the null hypothesis H_0 and the alternative hypothesis H_1. The null hypothesis represents the status quo, that is, the circumstance being examined and the purpose of hypothesis testing is always to try to reject the null hypothesis. The alternative hypothesis represents what the project desires to prove or establish, being formulated to contradict the null hypothesis (Barradas, 2012).

Table 3: Statistical tests

Obsevations	Minimum	Maximum	Mean	Typical deviation
98	-5.093	1.516	-1.963	1.310

Table 4: The procedure to evaluate the IF adjust to a normal distribution

Parameters	Values
μ	-1.963
Sigma	1.310

Table 5: Correlation tests

Statistics	Data	Parameters
Mean	-1.963	-1.963
Variance	1.716	1.716
Asymmetry (Pearson)	0.386	0.000
Curtosis (Pearson)	-0.098	0.000

D = 0.081; p-value = 0.530; $\alpha = 0.05$

Table 6: Statistical tests according to observed and critical values

Statistical tests	Values
Adjusted Chi-squared (observed value)	9.999
Adjusted Chi-squared (critical value)	14.067
α	0.05

It is well worth to clarify that for the adjustments normal log and gamma log distributions, it was necessary to perform a data transformation of Box Cox type, since, these methods do not research with negative values. However, the resulting values are not disturbed in their statistical or real value (Table 3).

Let's see, for example, the procedure to evaluate the IF adjust to a normal distribution with their respective results.

The risk of rejecting the H_0 null hypothesis when it is true is 53.02%. Considering that the level of significance is 5% which indicates a 95% confidence level in the results. From the test it is observed that frequency value IF (D) is lower than the p-value and in turn approaches zero which leads to the conclusion that the observed curve IF fits into a normal distribution (Table 4-6).

The risk of rejecting the H_0 null hypothesis when it is true is 18.86%. After the Chi-square test, we conclude that the observed value is less than the critical one that leads us to estimate that the observed frequency curve IF is adjusted to a normal distribution. The closer the observed value is to zero, the frequency curve will be adjusted to a normal distribution.

Once, the statistical analysis for the IF and CIF data has been made, it can be seen that when a normal distribution behavior occurs, the mean value corresponds to the result that most closely approximates the more general and real behavior. Only 14 scenarios for CIF are approximated with a confidence level of 95% of the value given by the CIF average.

In conclusion, the activities and factors pertaining to each of the 14 scenarios, guarantee a value of CIF in a degree of confidence of 95%. Some of the scenarios are.

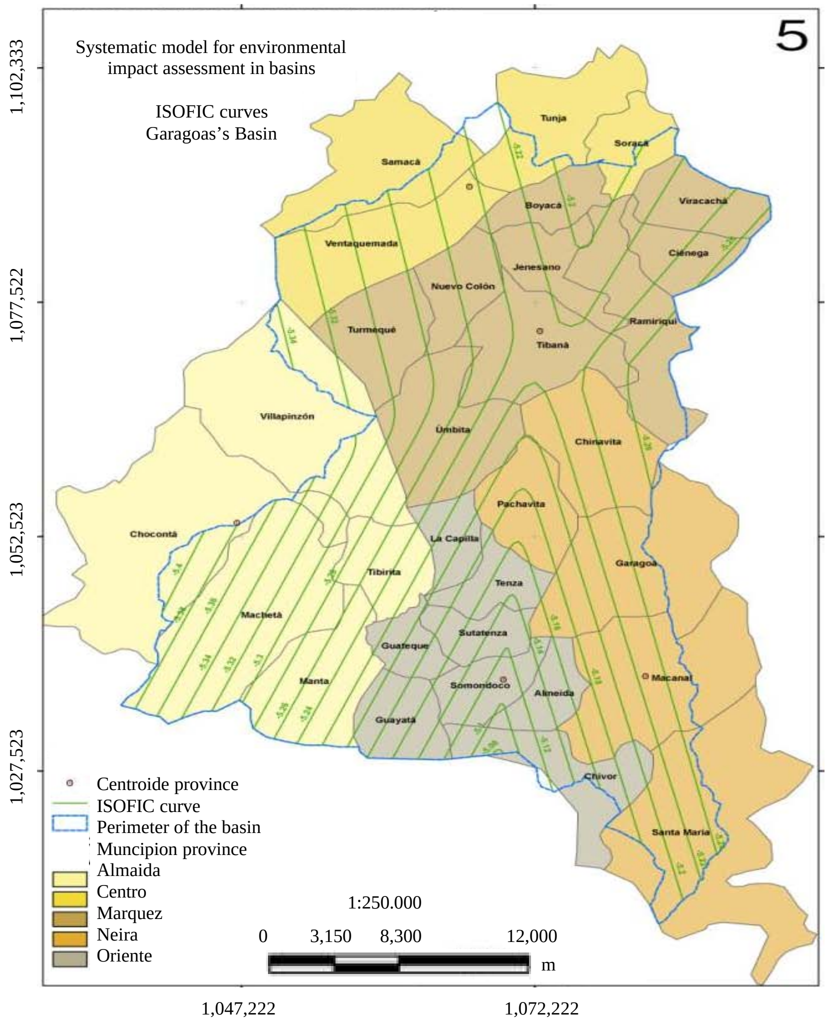

Fig. 4: ISOFIC map

Scenario 1; Factors: Hydro-metereological ecosystem, biodiversity, demographic, socio-cultural, historical landscape. Activities: road infrastructure, water supply works, containers for pottery, slaughterhouse, hydroelectric, poultry industries.

Scenario 2; Factors: Hydrometereological ecosystem, biodiversity and demographic, sociocultural, historical landscape. Activities: road infrastructure, sewerage works, electrical infrastructure, irrigation systems, buildings, pottery boilers, wastewater treatment plants, waste disposal. Hydroelectric, agroindustry, poultry industry. Education, health, trade projects, culture recreation and tourism, citizen security.

Interacting with the geographic information systems, a map can be presented at a municipal level that shows the total impact values resulting from the development of the model and which has been called the ISOFIC map. Figure 4 shows the curves of the same impact factors.

CONCLUSION

Considering that the model presented as IVAFIC in its phase 1 is of meta-heuristic type, it is essential that the field work for the elaboration of the EIA, develops a serious and dedicated that associates the authoritie's participation, field work and citizen participation, since, it is from this matrix that the model begins. This initial qualitative evaluation is the basis for validation of the numerical results obtained from the development of the model.

On the other hand, the features of quantification given by the researcher respond to the questions that at the level of a river basin is enough the assessing of the nature, durability and reversibility of an impact, that for the effects of the formulation of a plan of a river basin management and protection, constitute a starting element that diagnoses an order of magnitude the stage at which a basin can be found.

The calibration of the IVAFIC Model, in its phase 1, corresponding to obtaining the corrected impact factor CIF, through the sensitivity analysis that required the modeling of hundreds of scenarios likely to be the studied basin, which in turn may be scenarios equivalent to another river basin, generated, after the statistical analysis, an approximation to a normal distribution which sustains an even simpler and more dynamic exercise, under the proposed EIA matrix scenarios to be evaluated, which can lead us to estimate a value in order of reliable magnitude of CIF for a basin.

The proposed model is basically based on the application of geographic information systems, insofar as it can generate a map of partial or total values of CIF at the level of a municipality which favors the administrative, economic and environmental decision making at a local level when there is no information and capital is lacking to generate a study of this magnitude.

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