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Diffuse Logic: An artificial intelligence tool for the assessment of environmental quality in the Minero River Basin (Cundinamarca, Colombia).

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Abstract : This paper considers the use of diffuse logic artificial intelligence technique to emulate the evaluation performed by a group of experts in estimating the concurrent environmental quality evaluated in the conditions of the Minero River Basin (Cundinamarca, Colombia) integrating the variables water quality (BOD, TSS, $N\text{-}NO_2$ and P_{total}) and precipitation in a collaborative model.
Key Words : Environmental quality, fuzzy logic**,** watershed.

Introduction

The artificial intelligence technique called fuzzy logic or false fuzzy systems is used to treat uncertain or inaccurate knowledge, which does not require a mathematical model of the system. However, uncertainties and restrictions patterns, are included in descriptive procedure fuzzy inference instructions and also can express the control in an informally way and with linguistic labels based on expert knowledge [1,2]. This system has the advantage of making qualitative variables in quantitative through fuzzy sets, logical operators and mathematical expressions, i.e. analysis of an expert system, using reasoning models and managing uncertainty [3]. The rules (fuzzy rules that include all possible fuzzy relations between inputs and outputs) are taken from experts to then adapt and learn rules for the manipulation of the system, i.e., have allocation of the partial belongings of any object to different subsets of a universal joint, rather than completely belong to a single set , and the membership function assume values between 0 and 1, inclusive [4,5]. The membership function of a fuzzy set is [6]: $F = \{(u, u_f(u))/u \in U)\}$where $u_F(u)$ indicates the degree that the value of the variable u is included in the concept of F. This technique has been applied in decision making for reuse of wastewater, quality management and quantity of water, dynamic water and solutes, [3,7,8,9].Therefore, in this work the environmental quality in the Minero River basin (Cundinamarca, Colombia) will be assessed using the diffuse logic technique.

Among the most relevant research relating to this investigation are: the one made by [10], in this paper modeled cognitive uncertainty of perception of experts or consumers and statistical uncertainty in the data field using fuzzy logic to determine the quality of water in the Ganga river by the end of the year after the partial

implementation of pollution control strategies, where they concluded that the diffuse logic technique is a good tool for the measurement of water quality of the river for specific purposes. Other relevant research was conducted by [11], in which they developed a water quality index for public supply (IPS) using a fuzzy inference methodology. From the results obtained it was shown that the new procedure was more effective, compared to the classic IPS. Also, [12] present a fuzzy neural network model to evaluate water quality in the area of Suzhou in China since 1999-2002.Results indicated that the model is suitable for assessing water quality. Finally, the research done by [13], it was to analyze different investigations which have implemented quantitative models such as neural networks, fuzzy logic, genetic algorithms, integrated models, etc., using different parameters to determine water quality. In the future, it was necessary to use hybrid methods of these approaches with new optimization techniques, namely genetic algorithm (GA), optimization of particle swarm (PSO) and optimization of ant colony to improve the quality of the selection of features and to obtain better classification accuracy.

Materials and Methods

The method used is a combination of real and exact observation and knowledge of an empirical, complex situation and inductive reasoning, which would be to derive a new knowledge from particular phenomena and knowledge already obtained, and to establish propositions analyzed from their causes and real effects, i.e. from the particular to the general[14,15].It should be mention that according to the analysis and scope of the results, the type of research is analytical - quasi experimental, since it analyzes an event and understands it in terms of its obvious aspects, and also discovers elements that make up the totality and connections explaining their integration, i.e., promotes the study and deeper understanding of the event under study [16,17,18].

Precipitation information was obtained from the weather stations of the Cundinamarca Autonomous Regional Corporation (CAR) located in each of the municipalities belonging to the Mineroriver basin; information water quality parameters BOD, TSS, N-$NO_2$and P_{total}, as for surface water quality as plants wastewater treatment (including treatment flow) located in towns in to the basin in question, were taken from the Environmental Laboratory of the Cundinamarca Autonomous Regional Corporation (CAR).

Results

Using the Fuzzy Logic technique to establish the environmental quality, a categorization of the values of the variables analyzed in the surface water body, in environmental quality qualification of very low, low, medium, good (high) and very high Good (high) were due. Then he defined, as appropriate the *"membership functions",* which allow the post to establish the rules defining the calculation or in this case, the classification of environmental quality. The following functions are display:

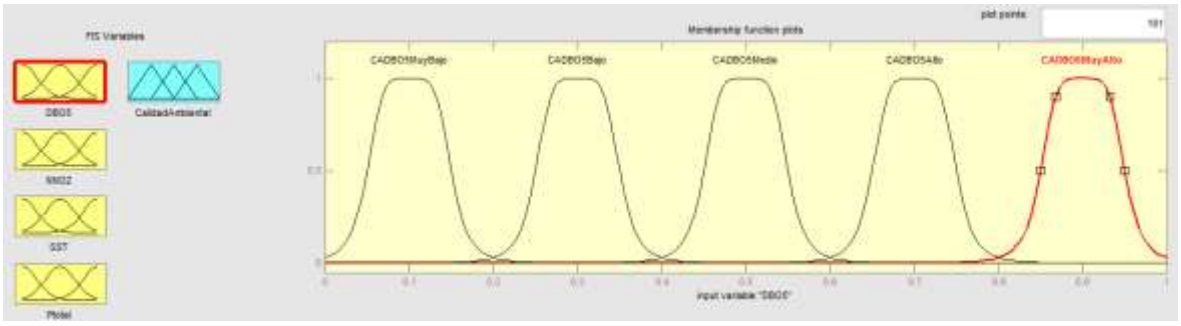

Figure 1.Established Fuzzy Functions.

In Figure 1, 4 input variables, and one output variable, are define in ranges previously specified. It was decide to use the gbellmf function *(Generalized bell-shaped membership function),* which allows much more diffuse classification categories compared to other options. Once the function has been define, we proceedto find the relation between variables that allowed generating a compendium of rules, in order to calculate the environmental quality from them, a task that in this case is not particularly simple, given the fact that we have 4

variables and each one with 5 possibilities. There are few methods to find a set of rules from the input variables, however, the measure J *(J-measure)*, offers a choice from conditional probability, concepts of entropy and using the data in time, find rules for a variable, with respect to its output:

$$J(B_T; A) = p(A) * \left(p(B_T|A) \log\left(\frac{p(B_T|A)}{p(B_T)}\right) + (1 - p(B_T|A)) \log\left(\frac{1 - p(B_T|A)}{1 - p(B_T)}\right) \right)$$

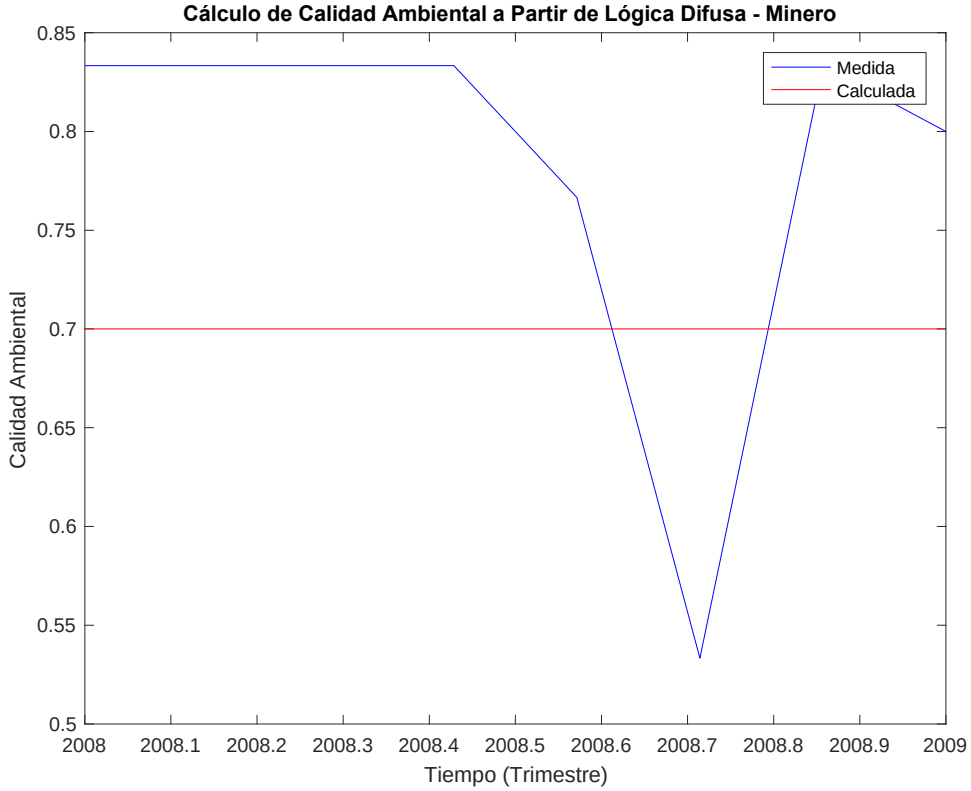

Figure 2.Comparison between the calculated and the expert environmental quality.

In figure 2, a linear constant (LD) value of low variation is observed in the estimation performed with regular qualification, whereas for the period 2008 - 2009, in the measured environmental quality (experts). It considers a variation in the period of the year 2008, of values between 0.5 to 0.85 indicating that the qualification is between regular and good.

The difference of values obtained between the expert and the calculated (LD), shows that the technique of diffuse logic fails to emulate the concepts emitted by the experts, and this is evidence by the absolute error that was obtained 0.1250 and the relative error 15.9573 % as shown in Table 1. This result and the difference between the measured (Experts) and the calculated (LD) would indicate that the system modeled with the fuzzy logic technique is not the ideal to emulate the concepts emitted by the group of experts. For this reason, a feedback process was carry out with the environmental experts of the results obtained and the model, in order to determine the possible causes of the differences in results. At the end of the process, the consensus of the experts was obtained that the main variable that influences the phenomenon that was not taken explicitly in the initial model was the precipitation, since the influence of this affects the measurements of the quality parameters of the water (BOD,, TSS, N-NO_2 and P_{Total}) so that precipitation helps to concentrate or dilute the contaminants analyzed in this surface water body.

Table 1.Performance measurement of the computational technique.

ComputationalTechnique	Mean Squared Error (MSE)		Testingcoefficientdetermination ($R^{2)}$		Relative Error	Absolute Error
	SuggestedValue	ValueObtained	SuggestedValue	ValueObtained		
Diffuselogic	≤ 0.10	0.1280	□ 0.90	N / A	15.9573 %	0.1250

In Table 1, it is observe that the obtained results of environmental quality by applying diffuse logic to emulate the results of environmental quality conceived by the group of experts in this body of surface water evidenced favorable values in terms of the relative and absolute error, in comparison with the literature. However, when comparing the values obtained when applying the technique versus the suggested values, it evidence that the mean square error (MSE) is outside the suggested range. Therefore, the proposed model serves as a tool for the analysis of the quality of surface bodies but should not be used as a sole criterion to determine the quality of water and makes it necessary to use the concept emitted by experts for environmental makingdecision.

Conclusions

When using fuzzy logic to estimate the environmental quality in the body of surface water, it is observe that the categorizations, relations between variables and combinations found in the abstraction of the environmental phenomenon, according to the qualification of pre-established environmental quality, are significant. The emulation of the environmental quality of the experts according to the performance results are adequate, but they are not sufficient for the environmental making decision, for which the concept of experts is necessary for making assertive decisions. By comparing the measured (expert) and calculated (diffuse logic) results, it presents a combined topology in the segments of observation that converge in a marked heterogeneity and high variability of the results of environmental quality, which establishes to condition the variable precipitation as influent in the phenomenon of concentrating or diluting the contaminants analyzed in this body of surface water.

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