ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11, S.Iss 05, 2022

AN EXTENSIVE REVIEW HIGHLIGHTING THE DIVERSE APPLICATIONS OF FUZZY SET THEORY WITHIN THE FIELD OF ENVIRONMENTAL ENGINEERING, EMPHASIZING ITS ROLE IN ADDRESSING COMPLEX AND UNCERTAIN PROBLEMS IN VARIOUS ENVIRONMENTAL SYSTEMS

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ABSTRACT

Numerous academics have described approaches to address the highlighted environmental issues while taking into account alternate assessments of environmental component processes that are mathematically rigorous and employ fuzzy logic and approximate reasoning. Several artificial methodologies have been described to demonstrate how such a method of computational intelligence would operate in carrying out an assessment. The use of fuzzy systems for environmental component analysis sets this method apart from earlier methods. In order to measure and manipulate subjective, fundamentally uncertain, or imprecise values and concepts in a mathematically valid manner, it makes use of sophisticated computer intelligence techniques like fuzzy logic. The application of fuzzy sets to environmental engineering was proposed in this work.

Keywords **:** Artificial intelligence, environmental factors, fuzzy set theory, and environmental variables

1. Introduction

It is evident that more appropriate methods are required to control the significance of environmental factors, interpret a suitable range for every metric, and integrate disparate parameters used in the evaluation process. In this regard, artificial intelligence has given rise to some alternative approaches. Real environmental challenges are being used to test these approaches, which mostly use fuzzy logic and fuzzy sets. Reducing the ambiguity and imprecision of the norms used in executive tools is the ultimate goal. [6, 10, 23]

Numerous academics have suggested using fuzzy sets theory-based techniques to deal with the ambiguity surrounding the analysis of concepts related to water, air, land, biology, and socioeconomics. Continuous efforts are intended to define environmental eminence by taking into consideration theory of fuzzy sets, keeping in mind The importance of managing

uncertainty Within the evaluation of environmental quality and the adaptability of fuzzy set conceptin deciding in the imprecise environment.

2. The Use of Fuzzy Set Theory in Environmental Engineering

Twenty number of groundwater samples were taken from town of Sohna in the district of Gurgaon located in Southern part of Haryana, India, using an optimization technique based on fuzzy rules by Bhupinder Singh et al. (2008). Nine of the fifteen physico-chemical parameters that were examined in these samples were utilized to evaluate their quality using a fuzzy synthetic evaluation approach. According to their findings, every water sample falls into an acceptable category with a certainty level between 44 and 100%. If no other source of water is available, water can be utilized for consumption without posing any health risks due to their physico-chemical properties.

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The Model of Fuzzy Soil Conservation Service Curve Number (SCSCN) was proposed by Carlos Roberto de Souza Filho andAurelio Azevedo Barreto-Neto (2008) as a method for forecasting runoff and, in turn, erosion of the soil and watershed eminence. By making minor adjustments to the program script, such software created can generate fuzzy restrictions with varying dimensions and be utilized with a variety of membership functions.

Yilmaz Icaga (2007) evaluated the quality classifying surface water using fuzzy logic and an index model. The approach involves converting conventional quality classifications into continuous forms, then using fuzzy rules to total the levels of concentration of the several parameters of quality (TDS, DO,pH, Cl,Na,NH_3,NO_2,$SO4$,NO_3,Color,), and lastly defuzzyfing these summed values to create the index. He came to the conclusion that continuous information, which is derived via fuzzy logic, may yield more accurate data.

In order to mimic the inaccurate and hazy relationships in river quality modelling, LI Ru-zhong (2007) applied fuzzy arithmetic based on the water system's fuzziness and imprecision. A fuzzy water quality model in two dimensions for abrupt pollution emancipation is created by specifying the model's parameters as symmetrical triangular fuzzy numbers. The α-cut approach and functions of triangular fuzzy numbers in mathematics can be used to retrieve the pollutant concentrations from the fuzzy model that correspond to the designated level of α. The study's findings indicate that using triangular fuzzy numbers to simulate river water quality is both theoretically possible and computationally reliable.

Based on the total concentration of Biochemical Oxygen Demand (BOD) in each drain, Ajit Singh et al. (2007) created the Model of Interactive Fuzzy Multi-objective linear Programming (IFMOLP)for managing quality of the water in a river basin. The model will first assess concentrations of dissolved oxygen (DO) or deficiencies in DO at a point in various spreads. They discovered that the approach gives the decision maker the freedom to freely define all of their goals. The many levels of aspiration for enhancing water quality and

lowering cost of treatment are determined by interaction with the DM, and the treatment levels' compromise solutions have been accomplished.

According to Sudhir et al. (2007), the theory of fuzzy sets is used to make decisions while evaluating the Groundwater's physicochemical qualities for human consumption. According to the quality classes' recommended limits set by various regulatory agencies and the views of drinking water quality specialists, the fuzzy synthetic evaluation model provides the certainty levels for the water's acceptability. 42 numbers of groundwater samples taken from the 15 numbers of villages in the Ateli block of South Haryana, India, serve as instances of using an optimization model based on fuzzy rules. In the end, they came to the conclusion that roughly 64% of the water sources were either suitable or desired for drinking.

Two distinct environmental protection organizations gathered data from the Ebro River in Spain, and William Ocampo-Duque et al. (2006) suggested a technique using fuzzy inference systems (FIS). to evaluate the quality of water. They created a fuzzy reasoning-based index of water quality.Regarding the pollution issues in the investigated area, their findings—which are organized inside a geographic information system—evidently concur with government information and professional judgments. As a result, this approach shows up as a viable and different instrument for creating plans for efficient water management.

The fuzzy contingent valuation approach (FCVW) is used in a technical analysis by Ho Wen Chen et al. (2005) to evaluate gains in in-stream water quality using three fuzzy resources: ecological, recreational, and aesthetic elements. According to the data compiled from the regression analysis, the overall advantages of the in stream quality of water enhancements are directly correlated with the local residents who are impacted by the in stream water quality.

Based on water quality measurements taken at specific stations throughout time, W. C. Ip et al. (2005) used an approach of data-mining to assess the Hang Jiang River's water quality. To establish the over-all level of water quality for the areas and time periods in question, they have whittled down the thirteen water quality criteria to four or five key ones. These characteristics are significant because they establish the DM rules, which in turn provide WQ measurements. Although it is crucial to take into consideration the differences in water quality, a significant attribute does not always indicate that a higher concentration of it would result in more polluted water. Using data on groundwater quality collected from 7 locations, including an industrial area of Kolkata, Dr. Arvind K. Nema and Rajneesh Rai investigated a fuzzy logic-based groundwater classification scheme. The classification was done using five constraints: BOD, temperature, nitrates, pH and fecal coliforms. To varying degrees of certainty, a sample of water can be categorized as terrible, medium, or good. Finally, it was determined that there are a lot of ambiguities in field data. Therefore, in this study, a unique approach based on fuzzy logic—a soft computing technique—has been used.

Shui-Ping Chang and Chih-Sheng Lee (2005) used three key assimilative capacity, economic and environmental factors considering quality of river water and waste water treatment cost—to illustrate the potential of the fuzzy interactive multi-objective optimization

approach. According to the case study, an advanced water quality level may be attained at the monitoring places in order to maintain the same equitable removal levels and to maintain an environmental and economic balance in a river system. By using trade-off processes, it also functions well in managing the water quality of water of a river basin. Three fuzzy synthetic evaluation techniques were used by Ni-Bin Chang et al. (2001) to compare the results of traditional processes, namely the Water Quality Index (WQI), with the water quality level of the Taiwan's Tseng-Wen River system. The results unequivocally show that the methods may effectively reconcile innate differences and decipher complicated situations. The Water Quality Program of Total Maximum Daily Load (TMDL) can also be verified with the use of fuzzy synthetic evaluation, which can also be valuable in developing a successful water quality management plan.

M pimpas Hercules et al. (2001) used fuzzy number shaving Triangular membership function to express the coefficient of physico-chemical quality and the pollution load of sources in a field investigation of pollution in the Gulf of Thermaikos using a water pollution model. The equation of advection-dispersion for 10 distinct variables of water quality is solved by means of a two-dimensional finite element approach in conjunction with analysis using fuzzy logic. The method is highly effective for identifying the extreme values of these qualities and produces the most confident value for each variable of quality measure.

An imprecision range and a level of confidence are added to the mean value of the numerical output by the fuzzy logic-based approach, which is a supplementary technique to deterministic physically-based modelling. Catherine Freissinet et al. (1998) came to this result after introducing a variety of imprecisions, either through measurement error or subjective or state-of-the-art estimates of coefficients. It appears to have a lot of potential for study on risk analysis.

A study on irrigation water requirement forecasting systems that might assist administrators in their operational work with relation to water distribution and delivery in irrigation schemes was carried out by Nobuya Saruwatarim and Atsushi Yomota (1995). By conducting field testing, they verified the system's availability and proposed using the forecasting system for basin water management. They also came to the conclusion that systematization that ignores human relations is pointless and never helpful because agricultural production was initially dependent on human activity.
Inakwu O. A. Odeh and Alex B. Mc Bratney (1997) proposed fuzzy logic applications in soil science, including soil numerical classification and mapping, modelling, land evaluation, and simulation of soil physical processes, fuzzy variogram and kriging of soil variables, grey-scale digital image analysis, fuzzy measures of imprecisely defined soil phenomena, and soil quality indices. Fuzzy set theory has a lot of potential in soil research, they concluded.

Using fuzzy synthetic evaluation approaches, Guleda Onkal - Engin et al. (2004) offer a technique for urban air quality in Istanbul's European section. This assessment included data on air pollutants, including carbon monoxide (CO), ozone (O_3), and total suspended particulate matter (PM) Sulfur dioxide (SO_2), nitrogen dioxide (NO_2), that were gathered at

five separate air quality monitoring stations situated in the western section of Istanbul. After comparing the results to the EPA air quality index, it was determined that these methods are comparatively appropriate for managing air quality of urban zone.

By conducting extensive field research on noise monitoring (as well as atmospheric conditions) and controlling and regulating techniques, Aluclu et al. (2008) developed a fuzzy logic model and described the noise–human reaction. They compared the model's results with a range of statistics, including correlation coefficients, max–min, standard deviation, average, and coefficient of skewness, as well as error modes, such as relative error and root mean square error, to ascertain that the model can be used for noise control in any workplace and that it can help the designer in the planning stage of a workplace. They found that the error modes were comparatively low, the correlation coefficients were notably high, and the other statistics closely matched the data.

An effective technique for conserving natural resources and safeguarding the environment is environmental impact assessment, or EIA. As a result, the majority of developed nations have included EIA into their laws, which require all projects to be approved (Council of European Union, 1996; EPA, 2007). Foretelling and evaluating all of the environmental effects that the project's implementation will inevitably have been part of this assessment.

EIAs are now conducted using a variety of approaches. Some more broadly applicable techniques have also been developed, even if the majority were created to evaluate the Environmental Impacts (EI) of particular projects (Erikstad et al., 2008;Conesa, 1997). To achieve a worldwide assessment of the various impacts, the most sophisticated EIA methodologies need the measurement of a variety of variables and certain parameters in order to estimate the values of the impact indicators. These values must then be transformed to a single environmental quality scale.

However, objective indicators (such as landscape quality, social acceptance and lifestyle quality) are often unable to adequately describe many environmental impact properties, and the estimation of these indicators' values is frequently impacted by a higher uncertainty and inaccuracy. Since the conversion of indicator data to a single environmental quality scale necessitates a diagnosis, which is frequently not free from subjectivity due to the numerous criteria and value judgments of householders, subjectivity and uncertainty are implicit in EIAs to some extent. In order to assess the effects, we might utilize expert criteria, data on the environmental impact of connected projects, the sensitivity of the affected population, environmental laws, etc. The systematic treatment of this data, which is often inaccurate and often relies on linguistic and non-quantitative characteristics, requires an appropriate technique. Thus, fuzzy logic that makes use of fuzzy arithmetic and approximate reasoning techniques could be a good way to create new EIA methods. [23, 28].

In the field of the environment, fuzzy logic has been successfully used. Surface water and sub-surface water treatment [36; 25], air pollution control [15], soil amendments [8], and various water, air and terrestrial ecosystem environmental research are only a few instances

of such applications that can be cited in the past 20 years. Other environmental matters like environmental indicator design [35;38], industrial green engineering [12], ecological impact classification [35],sustainable development [4],evaluation of environmental integrated models [24], sustainable development [4] life cycle [21] and risks [20], have also made use of fuzzy logic. Nevertheless, there aren't many published studies on fuzzy logic's use in environmental impact assessment. Anile et al. (1995) suggests using fuzzy arithmetic to evaluate Leopold's matrix. Fuzzy cross-impact simulation is a technique used by Parashar et al. (1997) for environmental evaluation. In order to evaluate environmental impact in fuzzy terms, Enea and Salemi (2001) suggest appropriate operators and outline a process where environmental components are defined by fuzzy numbers. Peche (2006) has published a study outlining the generalized modus ponens technique, a quality-based assessment of environmental impact that estimates each impact using the fuzzy inference method.

It's also imperative to note that the majority of published research on fuzzy logic-based environmental evaluations are based on a data base made up of a number of fuzzy directions and the fuzzification of the input components in order to apply them to the inference system. The risk assessment of groundwater contamination [37], assessment of quality of river water [27] and groundwater [6], and the executive process to evaluate environmental effects [13] are a few illustrative instances. All of the aforementioned techniques used fuzzy set theory to either a portion of environmental challenges or the current EIA methodology. None of the approaches used fuzzy set theory to address every aspect of the environment in a concise manner.

3. Conclusion

An effective method for evaluating various environmental concerns or the overall effect of carrying out tasks and projects is fuzzy logic. This is particularly relevant when quantitative data regarding environmental elements is brief, imprecise, ambiguous, and expressed in language. Therefore, the goal of this analysis is to outline a fuzzy logic-based procedure for conducting environmental issue analysis when uncertainty is present. However, in contrast to the previously mentioned procedures, this new approach develops an alternative method of applying fuzzy logic to environmental parameters.

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