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Developing a wet quality model using fuzzy approach for the Al-Gharraf River in Southern Iraq

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ABSTRACT

The present study develops a wet quality model based on fuzzy approach to assessment of the surface wet quality in Al-Gharraf River located in the South of Iraq. The wet quality parameters, including Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), Chloride (CL), Sulphate (SO_4), Nitrate (NO_3), and Phosphate (PO_4), were selected as input parameters to fuzzy wet quality model (FWQ). To evaluate the performance of the proposed model (FWQ) of Al-Gharraf River in the period of the study, the produces of our model were compared with those of the wet quality index (WQI) and Canadian Wet Quality Index (CWQI). They showed similar results and were sensitive to changes in the level of wet quality parameters. However, the model proposed in the present study produced a more stringent produces compared to the WQI and CWQI. Results from the simulation indicate that the sensitivity analysis of the suggested approach will be improved by almost (17%, and 24%) more than that achieved by the processes WQI and CWQI, respectively. In conclusion, the proposed index seems to produce accurate and reliable results and can be used as a comprehensive tool for wet quality assessment.

Keywords: Wet Quality; Fuzzy Approach; Al-Gharraf River; FWQ.

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1. Introduction

Rivers are considered as the most important source of fresh wet and the essential issue in the development of societies, in addition to that the protection and improvement of environment and human health are wholly related to availability of sources to adequate wet supplies [1]. Wet is the main requirement for basic survival and for economic development in all societies over world [2]. In spite of this importance, the river and aquatic live in real risk due to disposing of untreated or poor treated domestic sewage, industrial waste wet may be containing toxic matter, discharging or infiltration of seeding waste (manure and pesticides), and finally runoff or polluted rainfall. All these kind of wastes are responsible and consider the major sources for wet river pollution [3]. The physical and chemical characteristics of the wet bodies are generally used to assess and determine the degree of pollution [4]. In researches related to the wet environmental issues and resource management, it is essential to understand and evaluate the impact of pollution sources on wet resources [5].

Iraq depends wholly on surface wet from two rivers (the Tigris and Euphrates) and their tributaries. There are a lot of reservoir dams are built in order to store and accumulate wet on it [6]. While the dependence on ground wet as a part of wet resources is very limited and not exceed 14%, it is characterized as shallow unconfined or deep confined ground wet aquifers [7]. AL-Gharraf River is the main source of wet for many cities in the south of Iraq. It passes through the Wasit and Thi Qar provinces, branching off from the Tigris River in Alkut barrage in the middle of Al-Kut city. It's wet is used for a variety of purposes, including drinking, rearing Livestock, irrigation, and fishing [8]. There are many articles published concerning the wet quality of AL-Gharraf River in the last years, a study conducted by Ewaid and Abed to research the potential pollution sources along the river in the two years (2014 and 2015) [9]. Another research was conducted by Ewaid and Abed to establish a mathematical Wet Quality Index to measure the wet quality of the Al-Gharraf River [10]. The Canadian Council of Ministers of the Environment Wet Quality Index (CCME-WQI) was used to evaluate the wet quality of the Al-Gharraf River for aquatic life protection and irrigation [11]. Al-Abadi studied the possibility of utilizing three distinct data-driven approaches to simulate stage–discharge relationship at Gharraf River system, these approaches are multilayer perceptron with backpropagation artificial neural network (MLP), M5 decision tree model, and Takagi–Sugeno (TS) inference system [12]. Al-Mayah and Mashaanrabee carried out study documented the application of the Canadian Council of Ministers of the Environment Wet Quality Index (CCME WQI) for twenty one sites along the Al-Gharraf River from Kut Dam to its tail in the northern part of Nassiria city[13]. A comprehensive study has been made by Al-Mayah and Rabee to assess the wet quality of Al-Gharraf River using the overall Index of Pollution (OIP), on the river during 2016-2017 [14]. The quality and validity of wet by applying the arithmetic weight index (AWI) for the wet quality of irrigation was carried out by Mustafa et al. [15].

The development of more appropriate approaches to detect the major influence of wet quality parameters, the definition of a worthy run for each parameter, and the strategy used to combine different metrics included in the assessment process are all clearly needed and acknowledged. As a result, some elective processologies have created from artificial intelligence. One of these processologies, fuzzy logic and fuzzy sets, are being tried with real-world environmental concerns [16]. The innovation of this technique is to reduce the degree of ambiguity and imprecision in criteria used in decision-making.

Fuzzy logic gives a sense and beneficial process for categorizing, classifying the environmental situations furthermore for portraying both Human impact and normal varieties. While customary aides are made both considering fresh draws with irregular lines among them and on consistent elements whose scores are only vital to trained professionals, fluffy rationale sets make it possible to unite these approaches, can be used to describe, assess natural effects of a specific sort and it even gives formalism for overseeing lost data [17].

Many examinations utilized fluffy rationale deduction framework (FLIS) device to anticipate the wet nature of streams [16, 18-24]. It is prescribed that fluffy strategies should be applied to deal with the questions in the arrangement making on the wet quality.

Fuzzy sets have been effectively used to describe non-linear tasks, create induction frameworks based on expert experience, and cope with imprecise data. They are characterized by being theoretically simple to understand and based on natural language. [25, 26]. These benefits have been used to address wet-related complicated environmental issues. [27-31]. The present study aims to assess wet quality by developing a wet quality model based on employing wet quality fuzzy logic formalism has. The model was created based on the wet quality parameters, including Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), Chloride (CL), Sulphate (SO_4), Nitrate (NO_3), and Phosphate (PO_4), were selected as input parameters to fuzzy wet quality model. The performance of the proposed model was evaluated by compare it with the previous proposed models. The benefits and drawbacks of fuzzy logic in comparison to traditional techniques are explored and discussed.

2. Study area

AL- Garraf River is one of the most important surface wet resources in Iraq branches from the right bank of the Tigris Waterway in the upstream of the Kut Torrent. Along the Tigris River, several dams have been built espeially in the north part of Iraq suh as Mosul dam, Samarra Dam and Al Kut Dam for generating power and seeding [32]. Al-Kut Dam was established between (1934 and 1939) to feed the Gharraf stream, which branches before Al-Kut dam and the Tigris River. AL- Garraf River is the main source of wet supply for many cities in Wassit, ThiQar and Basrah governorates through Basrah canal as well as the districts along its bank. The stream continues to flow through the southern part of Wasit and the northern part of Thi Qar Governorates and passess through Al-Hay and Muwafaqiya districts with a total length of 90 km in Wasit province before entering Al-Fajr City in Thi Qar Governorates. The river enters Thi Qar Governorates and passes through Al-Fajr, Qalat Sukar, Al-Rifai and Al-Nasr districts. Then, it is divided into two branches in Albeda'a Barrage. The first portion finishes in a marsh flowing to Hammar, while the second one passes through Shatrah and Gharraf before ending in a series of smaller marshlands located in Al Hammar marsh (Figure 1). The river length from entering to its downstream in the marshland of Nasiriya is 168 km. There are four separate regulator structures on the Gharraf stream before Albeda'a Barrage was established in order to keep the high level of wet in the beginning of the stream (17.4 m) and Albeda'a (10 m) [33].

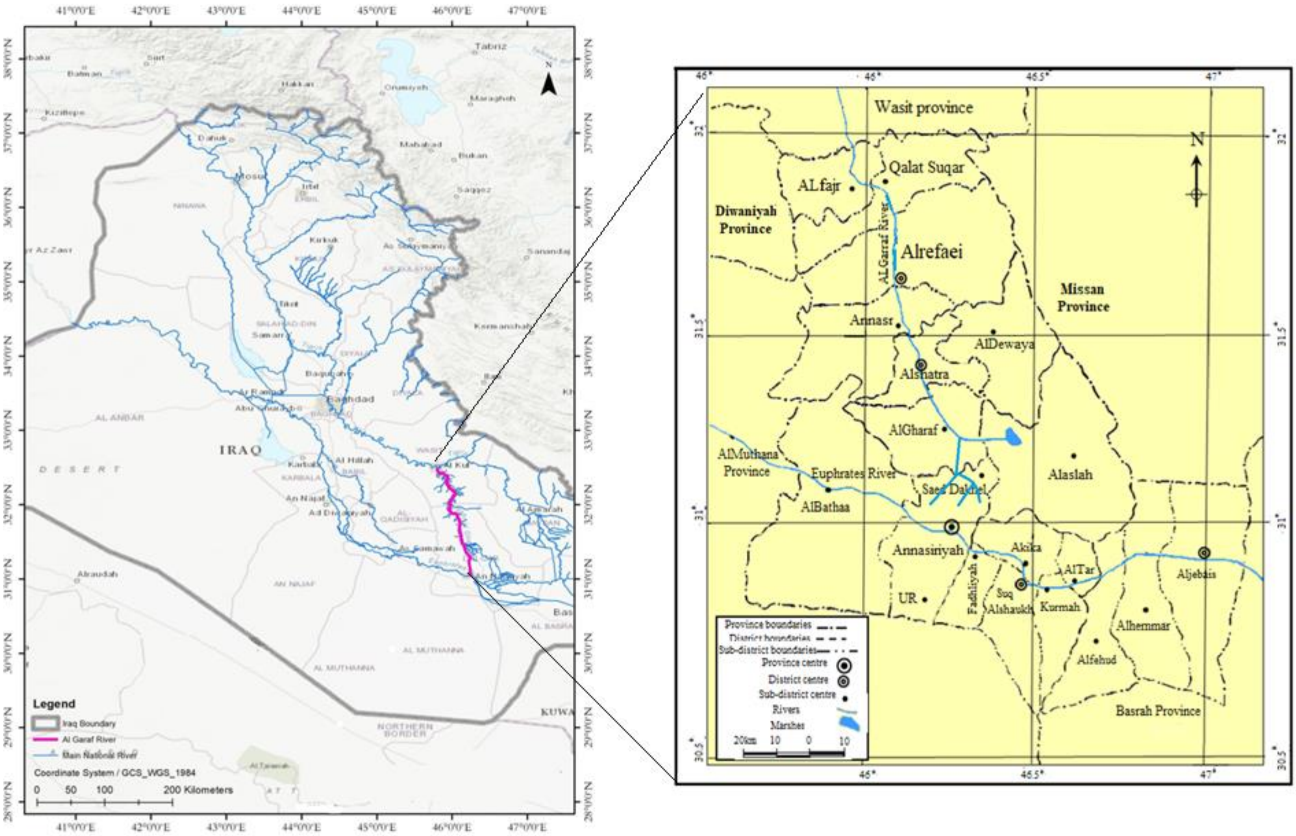

Figure 1. Location of AL- Garraf River on Iraq Map [34]

2.1. Sampling point

Sampling station was chosen from the stream located in Al-Hay and Muwafaqiya districts in Wasit province. The selection of these stations because most of previous models focused on the section within Thi-Qar province, Figure 2. In addition to that these stations are necessary to assessment and evaluate the quality of wet in River before entering Thi-Qar Province. The observed parameters used as input to fuzzy wet quality model are Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), (CL), (SO_4), (NO_3), and (PO_4).

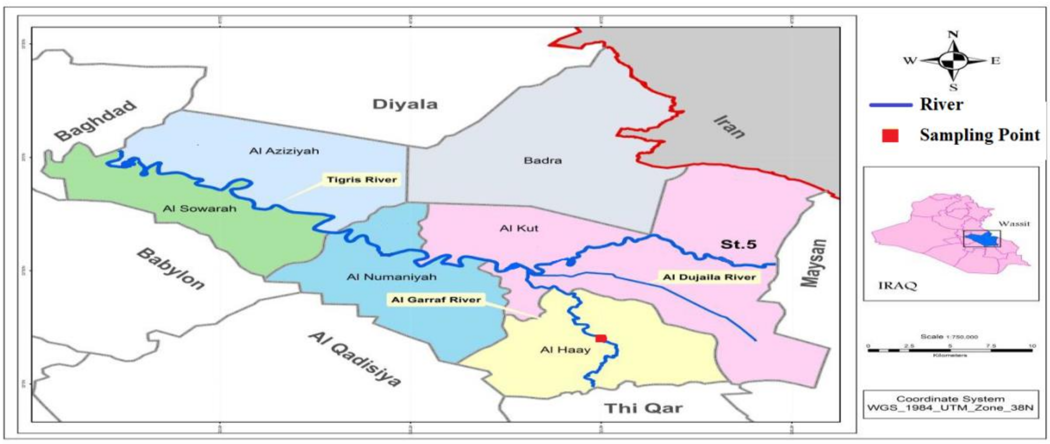

Figure 2. Location of AL- Garraf River on Thi-Qar province Map

2.2. Fundamental of fuzzy logic

In the mid-1960s, as an extension of the idea of the ordinary fuzzy set, Zadeh created the concept of fuzzy logic [35]. Because of its simplicity of design, stability, and ability to approximate to any nonlinear mapping, fuzzy logic's applications have been rapidly expanded in adaptive control systems and system identification [26]. The dynamic behavior of a system in fuzzy logic is described by a set of linguistic fuzzy verdicts based on human expert knowledge, which might be expressed by linguistic terms like small, medium, and large or acceptable and unacceptable. Fuzzy sets permit an matter to beome an incomplete individual from a set.
In Figure 3, if X denotes a group of items indicated by x, , X is commonly referred to as the discourse universe. So a fuzzy set A in X is defined by a set of ordered pairs, as represented in Eq. (1) [36].

$$A = \left\{\left(\frac{x,\mu_A(x)}{x}\right)\ x\ \in X\right\} \qquad \text{(Eq. 1)}$$

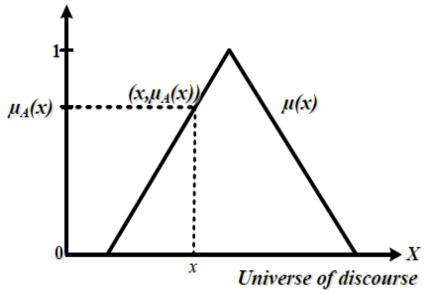

Figure 3. Membership tasks from the pair$(x, \mu_A(x))$

Where the capacity μ_A (x) shows the participation capacity of the article x in A. This capacity addresses a level of affiliation for each matter to a fluffy set and gives a planning of matters to a persistent participation esteem in the span [0...1]. Enrollment esteems near 1 (μ_A (x)→1) demonstrate that input x has a place with set A with a serious level. Little participation values (μ_A (x)→0), show that set A sometimes falls short for input x quite well. In fluffy frameworks, the powerful conduct of a framework is described by a bunch of etymological fluffy guidelines in view of the information on a human master. These principles are the core of a fluffy framework and might be given by specialists or removed from mathematical information. Regardless, the principles could be communicated as an assortment of In the event that assertions (On the off chance that predecessors, consequents). Precursors and consequents of a fluffy verdict structure the fluffy info space and fluffy result space individually, and are characterized by mixes of fluffy sets. By considering a fluffy framework with p information sources and one result with M guidelines, the L^th verdict has the structure [37]: R^L : In the event that x1is F_1^L and … x_P is F_P^L, y is G^L where F_1^L … F_P^L and G^L indicate the phonetic factors characterized by fluffy sets and L = 1… M.

Figure 4 shows the common construction of a fluffy framework which comprises of four parts: fuzzification, verdict base, deduction motor, and defuzzification [35]. The cycles made by fresh data sources are planned to their fluffy portrayal in an interaction called fuzzification, which includes applying participation undertakings, for example, three-sided, trapezoidal, and Gaussian. The induction motor cycle maps fuzzified contributions to the standard base to deliver a fluffy result. A subsequent of the standard and its participation to the result not entirely settled here. The defuzzification interaction changes over the result of a fluffy verdict into fresh results by one of the defuzzification systems.

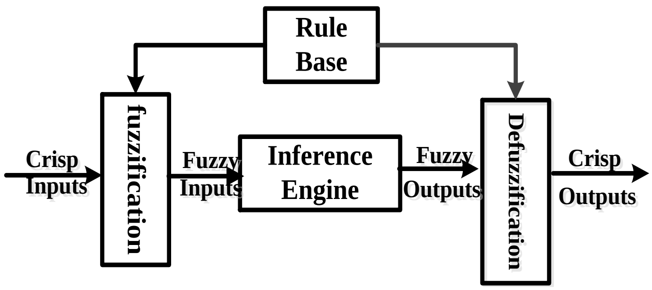

Figure 4. Regular construction of the fluffy processology

3. The proposed process

3.1. Implementing fuzzy logic in wet quality

This section describes the main matterive of the fuzzy approach in wet quality. The fuzzy logic is used to calculate the optimal value of the wet quality. Additionally, six linguistic variables are defined, which depends on the Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD) , (Cl), (SO_4), (NO_3), and (PO_4) (Figure 5).

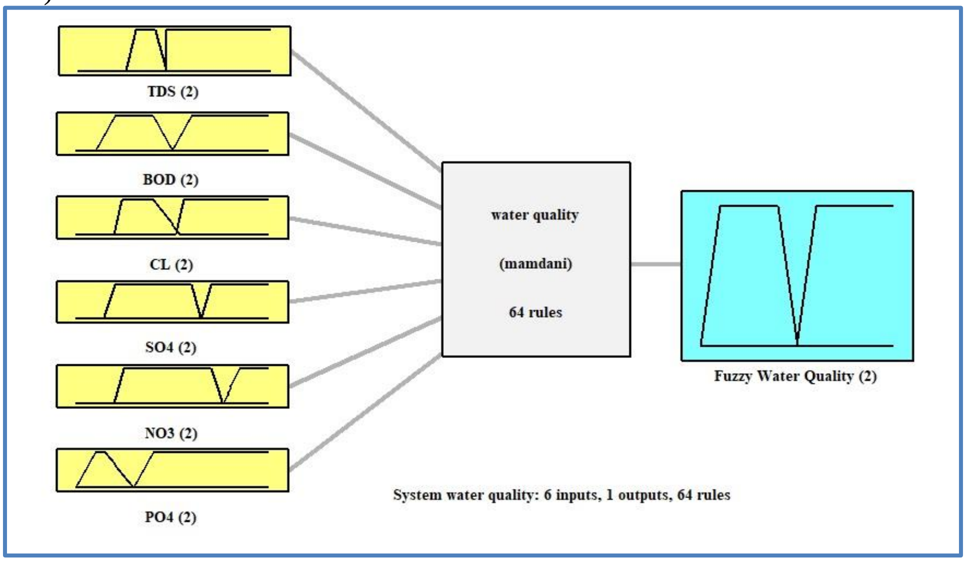

Figure 5. Fuzzy structure with six inputs (TDS, BOD, Cl, SO_4, NO_3, and PO_4, and one produce of Fuzzy Wet Quality)

Wet quality can be surveyed by its physicochemical and bacteriological elements. In this review, the six previously mentioned wet boundaries are utilized to plan a simple model to comprehend file for evaluating wet quality. The enrollment assignments got from the boundaries inside the FWQ are displayed in Figure 6. Figure 6 and Table 1 show the suggested process using two membership tasks for each input (TDS, BOD, CL, SO_4, NO_3, and PO_4, and one produce variable of Fuzzy Wet Quality) with universal of discourse ranges of [0…2000], [0…10], [0…250], [0…500], [0…20], [0…1], and [0…100].

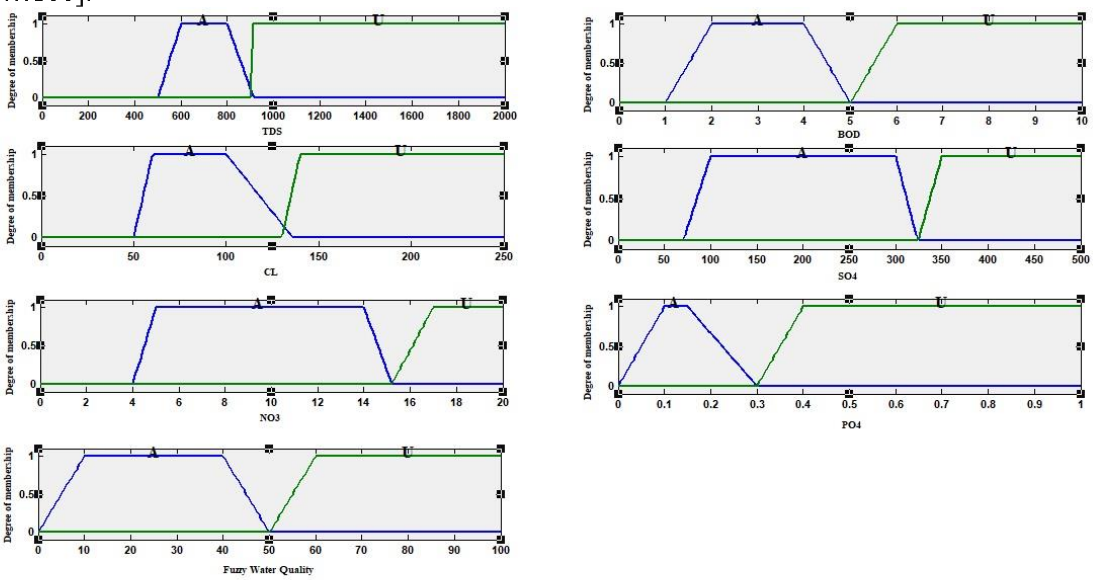

Figure 6. Membership graph for six inputs (TDS, BOD, CL, SO_4, NO_3, and PO_4, and one produce of Fuzzy Wet Quality)

Table 1. Fuzzy membership linguistic terms for the Fuzzy Wet Quality (FWQ)
Where A= Acceptable , U= Unacceptable

No.	Category	Parameters	Units	A= Acceptable				U= Unacceprable				Range
				a	b	c	d	a	b	c	d	
1	Psychochemical Properties	TDS	mg/L	500	600	800	914	900	910	>2000	>2000	[0...2000]
2		BOD	mg/L	1	2	4	5	5.1	6	>10	>10	[0...10]
3		CL	mg/L	50	60	100	136	130	140	>250	>250	[0...250]
4		SO_4	mg/L	70	100	300	324	325	350	>500	>500	[0...500]
5	Minerals	NO_3	mg/L	4	5	14	15.2	15.2	17	>20	>20	[0...20
6		PO_4	mg/L	0	0.1	0.15	0.3	0.3	0.4	>1	>1	[0...1]
7	(-)	FWQ	mg/L	0	10	40	50	50	60	>100	>100	[0...100]

Every boundary as an info is appointed to one of the five fluffy sets as far as enrollment undertakings. In view of the information introduced in Table 1, the fluffy sets are created by the accompanying condition:

$$Trapezoidal: f(x;a,b,c,d) = \begin{cases} 0 & x < a \; or \; d < x \\ \frac{(a-x)}{(a-b)} & a \le x \le b \\ 1 & b \le x \le c \\ \frac{(d-x)}{(d-c)} & c \le x \le d \end{cases} \quad (1)$$

In the fluffy processology, the fuzzified values are handled by the induction motor, which comprises of a standard base and different strategies for deducing the guidelines. Tables 2 and 3 and Figure 7 show the on the off chance that verdicts utilized in the proposed technique. The framework in this study contains number of 2^6=64 guidelines, 6 information sources and 1 result, and is used for planning a fluffy wet quality list (FWQ) for Al-Gharraf Stream. The result gives the wet quality with 2 sorts and is portrayed by the participation undertakings which plan the etymological factors (Figure 6). For instance, Assuming that TDS is A, Body is A, CL is A, SO4 is U, NO3 is U, and PO4 is U THEN Fluffy Wet Quality is A. These multitudes of verdicts are handled in an equal way by a fluffy deduction motor. The defuzzification tracks down a solitary fresh result esteem from the arrangement fluffy space. This worth addresses the wellness work worth of wet quality. Practice defuzzification is performed utilizing focal point of-gravity technique given by Eq. (11).

$$FWQ = (\sum_{k=1}^{n} U_k * C_k)/\sum_{k=1}^{n} U_k \quad (11)$$

Where U_k is the produce of verdict base , and $C_k$is the position of the produce membership function.

Table 2. IF-THEN Verdicts when the Fuzzy Wet Quality (FWQ) is Acceptable
Where A= Acceptable , U= Unacceptable

No.	TDS	BOD	CL	SO_4	NO_3	PO_4	FWQ
.1	A	A	A	A	A	A	A
.2	A	A	A	A	A	U	A
.3	A	A	A	A	U	A	A
.4	A	A	A	A	U	U	A
.5	A	A	A	U	A	A	A
.6	A	A	A	U	A	U	A
.7	A	A	A	U	U	A	A
.8	A	A	A	U	U	U	A
.9	A	A	U	A	A	A	A
10	A	A	U	A	A	U	A
11	A	A	U	A	U	A	A
12	A	A	U	A	U	U	A
13	A	A	U	U	A	A	A
14	A	A	U	U	A	U	A
15	A	A	U	U	U	A	A
16	A	A	U	U	U	U	A
17	A	U	A	A	A	A	A
18	A	U	A	A	A	U	A
19	A	U	A	A	U	A	A
20	A	U	A	A	U	U	A
21	A	U	A	U	A	A	A
22	A	U	A	U	A	U	A
23	A	U	A	U	U	A	A
24	A	U	A	U	U	U	A
25	A	U	U	A	A	A	A
26	A	U	U	A	A	U	A
27	A	U	U	A	U	A	A
28	A	U	U	A	U	U	A
29	A	U	U	U	A	A	A
30	A	U	U	U	A	U	A
31	A	U	U	U	U	A	A
32	A	U	U	U	U	U	A

Table 3. IF-THEN Verdicts when the Fuzzy Wet Quality (FWQ) is Unacceptable
Where A= Acceptable , U= Unacceptable

No.	TDS	BOD	CL	SO_4	NO_3	PO_4	FWQ
.1	U	A	A	A	A	A	U
.2	U	A	A	A	A	U	U
.3	U	A	A	A	U	A	U
.4	U	A	A	A	U	U	U
.5	U	A	A	U	A	A	U
.6	U	A	A	U	A	U	U
.7	U	A	A	U	U	A	U
.8	U	A	A	U	U	U	U
.9	U	A	U	A	A	A	U
.10	U	A	U	A	A	U	U
.11	U	A	U	A	U	A	U
.12	U	A	U	A	U	U	U
.13	U	A	U	U	A	A	U
.14	U	A	U	U	A	U	U
.15	U	A	U	U	U	A	U
.16	U	A	U	U	U	U	U
.17	U	U	A	A	A	A	U
.18	U	U	A	A	A	U	U
.19	U	U	A	A	U	A	U
.20	U	U	A	A	U	U	U
.21	U	U	A	U	A	A	U
.22	U	U	A	U	A	U	U
.23	U	U	A	U	U	A	U
.24	U	U	A	U	U	U	U
.25	U	U	U	A	A	A	U
.26	U	U	U	A	A	U	U
.27	U	U	U	A	U	A	U
.28	U	U	U	A	U	U	U
.29	U	U	U	U	A	A	U
.30	U	U	U	U	A	U	U
.31	U	U	U	U	U	A	U
.32	U	U	U	U	U	U	U

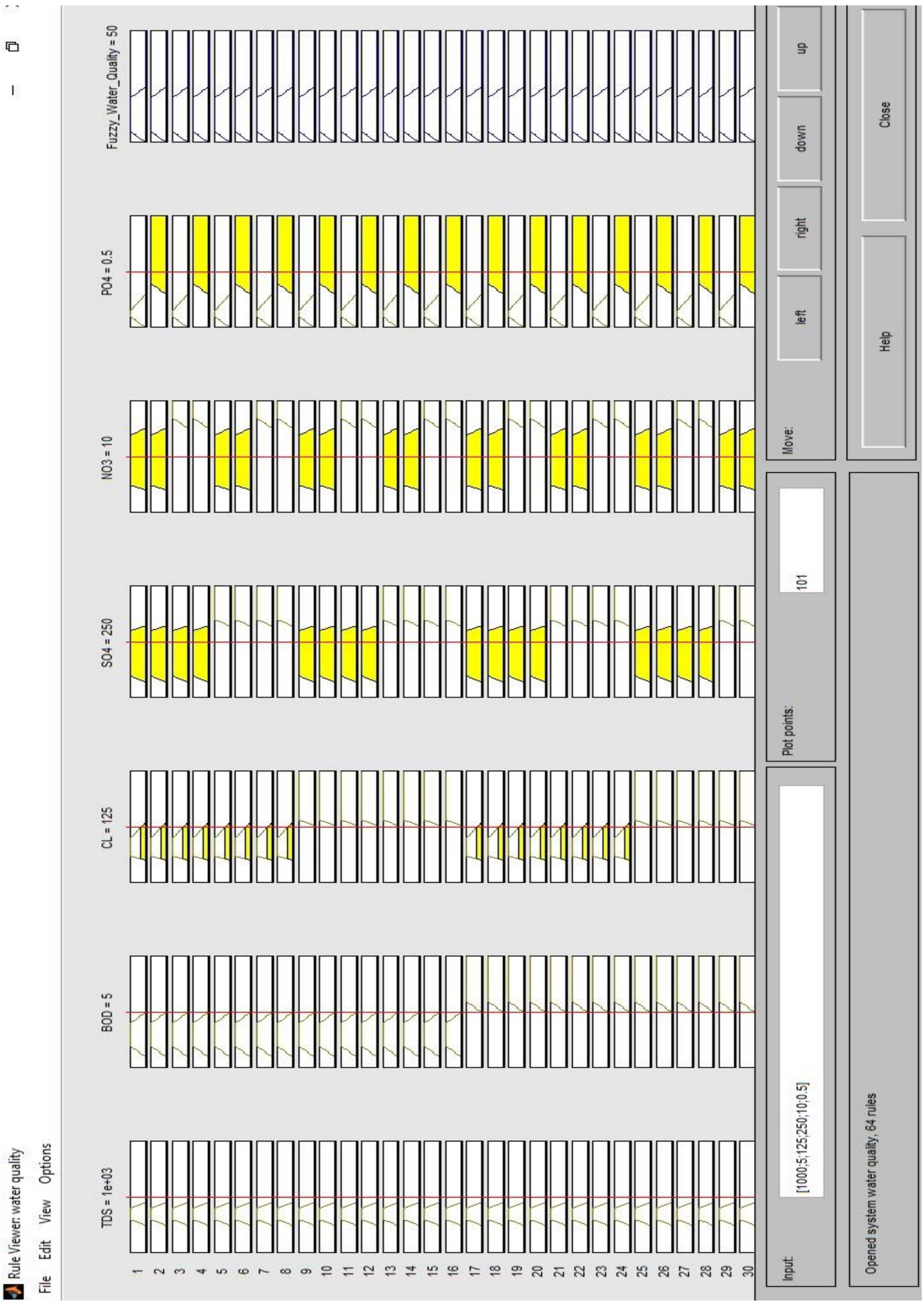

Figure 7. IF-THEN verdicts used in the proposed process for six inputs (TDS, BOD, CL, SO4, NO3, and PO4, and one produce of Fuzzy Wet Quality)

The strength of the FWQ file relies upon the kind of wet quality factors and the quantity of verdicts utilized. Nonetheless, expanding the quantity of boundaries and verdicts makes the model hard to plan [38].

4. Results and discussion

In this review, every one of the six info boundaries is characterized into two classes and characterized by a trapezoidal enrollment capacity to show how focuses in each information variable are diagrammed to a participation value. The participation undertakings are planned as displayed in Figure 6. Figs 7 and 8 show the Matlab verdict surface diagram of the connection between factors of the fluffy boundaries with the scores of the wet quality for instance.

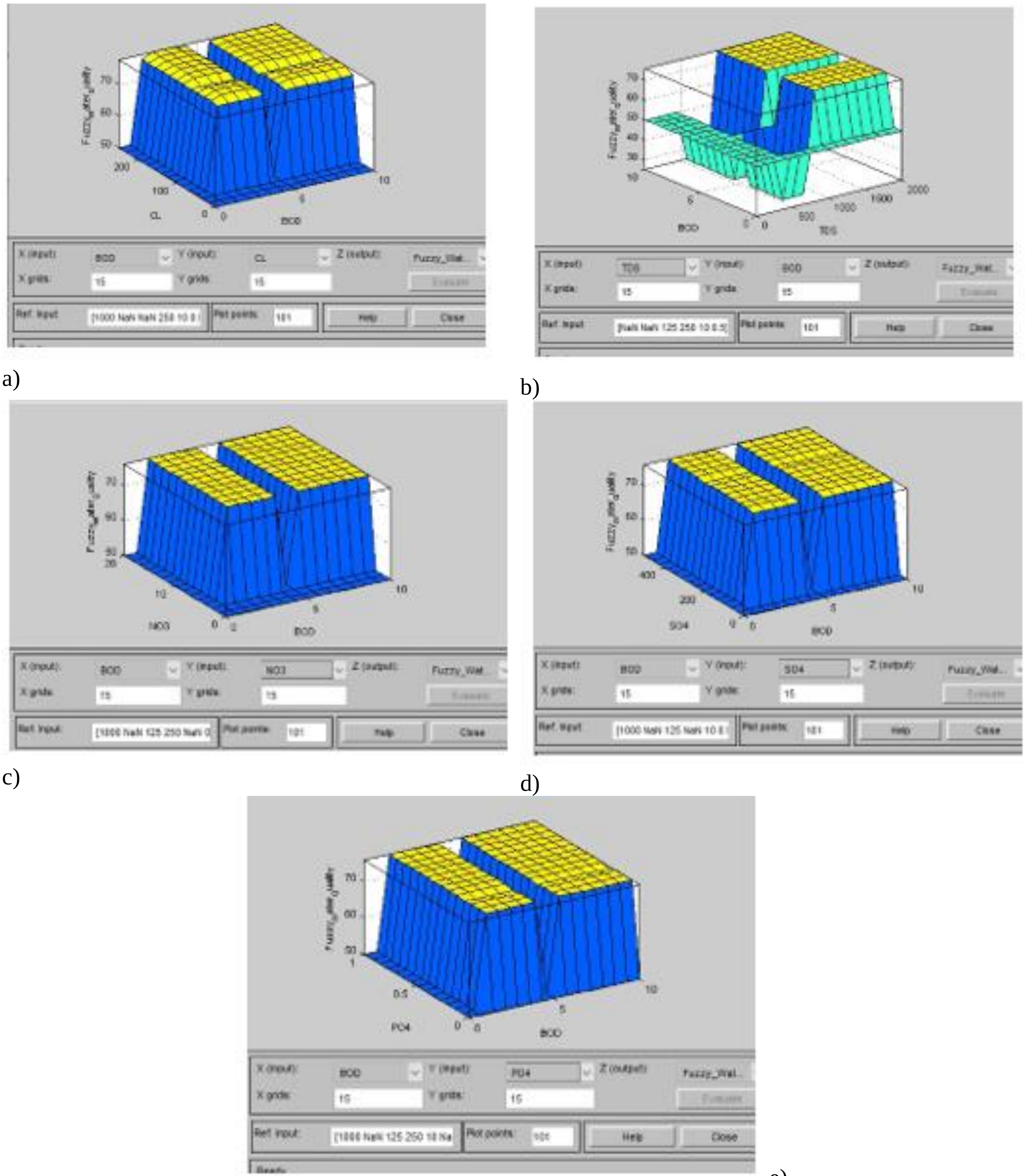

Figure 8. Surface for membership parameters in the proposed process (a= BOD and TDS), (b= BOD and CL), (c= BOD and SO_4), (d= BOD and NO_3), and (e=BOD and PO_4) for Fuzzy Wet Quality

Whenever the principles watcher in Matlab fluffy rationale tool compartment was utilized to enter different information esteems, the framework delivered the right results as per the guidelines. For instance, when the sources of info were the Iraqi guidelines values for wet boundaries, TDS, Body, CL, SO4, NO3, and PO4 (2000,10, 250,500, 20,1) individually, the FWQ was 32, which demonstrated an incentive for wet quality since the six boundaries were inside the permitted range. It is essential that the wet waterway, which is An as per the FWQ needs, ought to be treated prior to utilizing for drinking since there are various parts which impact the quality like turbidity, taste, and smell.
Figure 9, displays the comparison of the model indexes (WQI [39], CWQI [21] and proposed process (FWQ). As the number increases in the index, the proposed process performs better than the two approaches (WQI and CWQI), since it has good quality for wet in AL-Gharraf river. The wet quality could be accomplished by the proposed technique expanded by almost (17%, and 24%) more than that got by (WQI, and CWQI) models individually, which demonstrates that abetter power balance in a WSN could be accomplished by the proposed strategy.

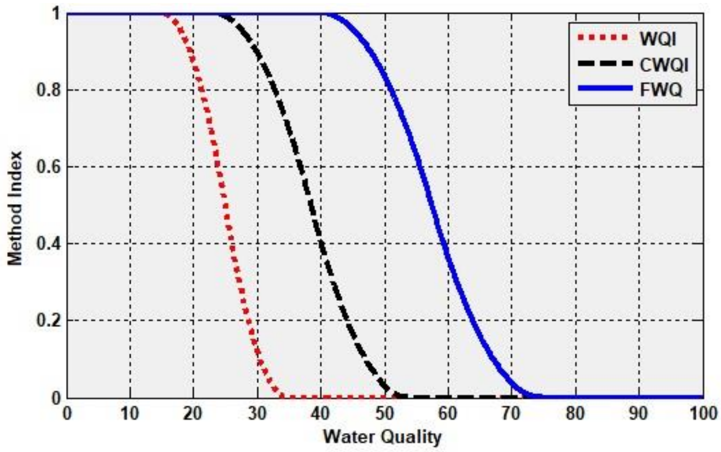

Figure 9. Wet quality for different three models (WQI, CWQI, and Proposed process FWQ)

5. Conclusion

The fuzzy approach, which was used to evaluate wet quality in this study, offers an easy illustration of the physiochemical properties to reach the generally nature of surface wet for various purposes. In light of specialists suppositions and public encounters, six wet quality boundaries (TDS, Body, Chloride, Sulfate, Nitrate, and Phosphate) were utilized as the marker boundaries to assess the nature of the waterway wet. The utilization of this file was checked by entering different info values to verdicts watcher of the Matlab fluffy rationale tool stash from the informational collection of Al-Gharraf Waterway.

The utilization of this model was exhibited at a testing station on Al-Gharraf Stream in Alhay station prior to entering Thi-Qar Region, in view of the noticed wet quality information. The fluffy model showed that wet quality had high supportability with the normal outcomes in Al-Gharraf Waterway. The proposed model can help chiefs in observing and detailing the state of wet quality for researching spatial and fleeting changes in the stream. As indicated by the recreation results, fluffy rationale ideas, whenever utilized intelligently, could be a successful device for a portion of the natural arrangement matters. The future expectation of wet quality conceivable decides when involved the FIS subject to different information verdicts for Al-Gharraf waterway and other Iraqi streams. Also, it very well may be utilized to decide the adequacy level for every individual boundary by alluding to the fixation ranges as per the chose reason.

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Declaration of competing interest

The authors affirm that none of the materials discussed in the current work are the subject of any known non-financial or financial conflicting interests.

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