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Neural Network Model for Water Parameter Prediction and Evaluation: A Case Study of Pipar City, Rajasthan, India

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ABSTRACT

This study presents the model of the neural network for sodium adsorption prediction sodium carbonate residual, magnesium adsorption, Kelly ratio and sodium percentage in groundwater samples of Pipar city, Jodhpur, Rajasthan. Diverse physicochemical parameters including pH, EC, TDS, Ca, Mg, Na, K, Cl, HCO_3, CO_3, SO_4 and NO_3 were tested for 50 groundwater samples for the pre-monsoon season of 2021. The ANN model, then contrasted with MS-Excel, is created with R programming. The right algorithm and neuronal numbers have been determined for optimizing the model architecture Via a responsive analysis, seven neurons were optimized through the resilient back propagation algorithm for weight-back monitoring. It was found that the prediction of irrigation appropriateness indices with a seven-neuron network was highly accurate. The relative mean squared error, coefficient of decision (R^2) and mean absolute relative error is calculated for the experimental outcomes and model outputs. There is a close harmonization between actual data and ANN groundwater outputs for irrigation suitability indices for the planning and analysis of datasets. For measured and projected values, spatial distribution maps have been created. The ANN model therefore seems to be a valuable tool in Pipar city, Jodhpur, Rajasthan, India to forecast groundwater suitability.

Key words: *Water Parameter, Neural Network Model, Pipar city, pH, SAR, Kelly ratio.*

Introduction

Raheli, *et al. (*2017) reported that precise prediction of chemicals in large river systems is the required challenge for management of water quality, environmental wellbeing and Overall River systems health planning. Tarun Gehlot *et al*. (2020) studied linear regression model which has been established between DO/BOD, COD/DO, BO D/COD, C O D / pH, BOD/pH and DO/pH. R^2 ranged from 0.889 to 0.034 between these parameters. Than a multivariate linear regression model has been set up for BOD and COD as dependent variable and DO, TEMP, TDS and pH as four independent variables. Performance of MLR Model has been justified with statistical variables like average square root error (ASRE) and

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universal efficiency (UE) (Kangyang Chen *et al.*, 2020; Lei Li *et al.*, 2021).

Kangyang Chen *et al.* (2020) reported that It is possible that machine learning models will be based on training models as well as on the consistency of the data. Also, in order to increase performance and minimize costs, the main water parameters should be recognized by the models. Mehdi Bahiraei, Saeed Nazari *et al.* (2020) reported that Multi-Layer Perception (MLP) neural network optimized by the Imperialist Competition Algorithm (ICA) and Genetic Algorithm (GA) is employed for predicting the water productivity. The ensemble models (GAMLP and ICA-MLP) estimate the pattern of targets better than the common MLP. Hang *et al.* (2020) studied A new BP neural system (BPNN) dynamic prediction model (WCA-BPNN) water cycle optimization algorithm was developed in the region of the Three Gorges Reservoir in China Landslide occurred, and 4-year data for time-series analysis and modeling is utilized for displacement tracking (Mehdi Bahiraei, *et al*., 2022; Meng *et al.*, 2021; Pariharsangeeta *et al.*, 2022).

Ying Deng *et al.* (2021) reported statistical models of the HKs in order to approximate their frequency in potable water is a possible alternative, but no research for HKs modeling is yet possible. Results have shown that RBF and BP ANN's total prediction capacity is greater than that of linear / log models. The RBF ANN findings showed that the dynamic nonlinear relationships between HKs and their associated water quality could be well understood and that the practice of HKs is a new approach to forecast (Raheli *et al.,* 2017).

Meng *et al.* (2021) found that bechmark models has superior feasibility for water parameter predations like biochemical oxygen requirement (BOD). Samples values extracted from waste water treatment units. Lei Li, Shuming Rongetal (2021) found that Artificial intelligence (AI) has shown steadily the capacity to overcome the complexities of drinking water treatment thanks to the extensive autonomous learning and the ability to resolve complex problems (DWT). AI technology offers technological assistance for DWT process control and service that is more effective than relying entirely on human operations. Data review based on AI and development learning processes was able to carry out a diagnosis of water safety, independent decision-making, and the optimization of operating procedures. Briefly, this study presents DWT-based AI technologies. Wen-jing Niu, *et al*. (2021) reported that Precise rainfall forecasts play a crucial role in ensuring the safe use of water supplies and their maintenance. Artificial intelligence tools can offer new predictive possibilities where the physical connection underlying can't clearly be reached. In order to fill this research void, the ability of 5 artificial methods of intelligence in everyday stream flow prediction is investigated namely artificial neural network (ANN), adaptive neural fuzzy inference system (ANFIS), extreme learning machine (ELM) (SVM). The assessment benchmarks are selected for four quantitative statistical indices ((Wen-Jing and Zhong-Kai, 2021; Ying Deng *et al*., 2021; Zhang, *et al.*, 2020).

Study Area, Methodology and Testing

This research has been conducted for Pipar City Jodhpur District of Rajasthan. Jodhpur district is situated between 250 51'08" & 270 37'09" North latitude and 710 48'09" & 730 52'06" East longitude covering geographical area of 22,850 sq km. Mean annual rainfall (1971-2021) of the district is 374 mm The temperature varies from 49 degrees Celsius in summer to 1 degree Celsius in winter.

Fig. 1. Map of Pipar City Jodhpur Rajasthan (INDIA)

Irrigation adequacy of soil water is dependent on the levels of cations and anions contained in groundwater. A computing device called neurons, which is bound to one another by a series of weights, is the artificial neural network. It accepts numbers of inputs, summing them up, applies a partiality, and uses results for a unique value, the transfer function, which leads to the output of the neurons. The objective of this analysis is to establish an integrated ANN model to assess the feasibility of the groundwater for irrigation. In order to forecast values, the ANN resilient back propagation algorithm is used. The various thematic maps were designed to de-

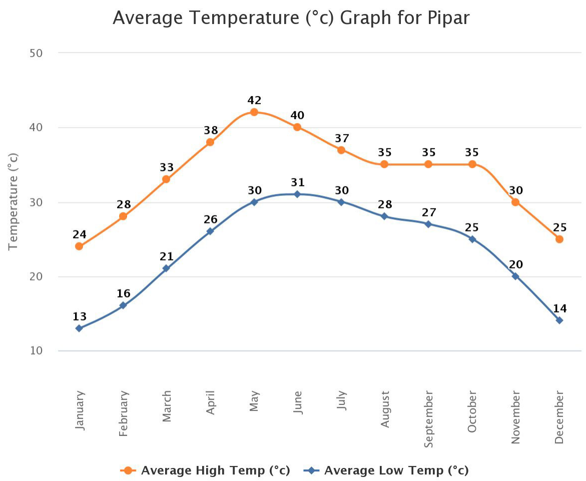

Fig. 2. Average rainfall for Pipar City Jodhpur Rajasthan (INDIA)

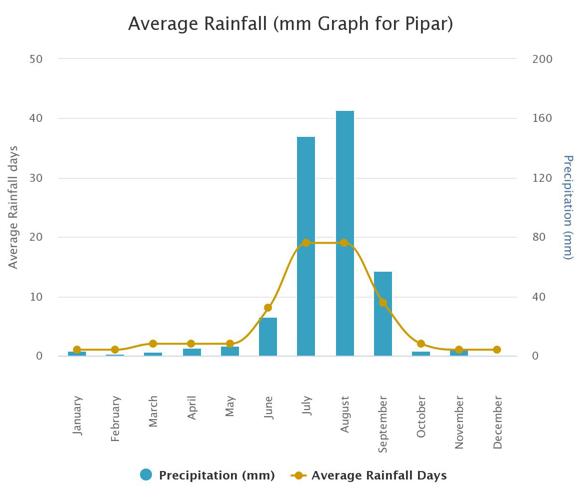

Fig. 3. Average Rainfall (mm) for Pipar City Jodhpur Rajasthan (INDIA)

scribe the spatial change between the values observed and projected. This research will be important in identifying the water suitability for irrigation, especially in a dry and semi-arid climate. During the pre-monsoon season of 2021, fifty relevant groundwater samples were obtained from sites of Pipar city. MS-Excel programme being utilized for statistics outputs and ANN investigation. ArcGIS 10.2 programme displays spatial distribution diagrams with observed and expected values for enhanced integration.

Neural Network Model & Results

Multilayer perceptron (MLP) with back propagation

Table 1. Technique and corresponding water parameter

Parameter	Technique
pH	Multi Parameter PCS Tester35
EC	
TD S	SUM (Cations and Anion)
Ca	Titration
Mg	
CO_3	
HCO_3	
CL	
TH	
Na	Flame photometer
K	
SO_4	UV Spectrophotometer
NO_3	
SAR	$Na^+/\sqrt{(Ca^{2+}+Ma^{2+})/2}$
RSC	CO_3 + HCO_3 - (Ca+ Mg)
KR	Na+ / Ca^{+2} +Mg^{+2}
MAR	Mg/ (Ca+ Mg)*100
% Na	$[(Na^+ + K^+)/Ca^{+2}+Mg^{+2} + Na^+ + K^+)*100$

(BP) algorithm has been utilized in designing dissimilar structures of the neural network. Expression for an output value of a three layered MLP is as follow:

$$y_k = fo[\Sigma_{i=1}^{MN} W\,kj \times fb\,([\Sigma_{i=1}^{MN} W_{ji}X_i + W_{jo})+W_{ko}] \quad .. (1)$$

Numerous neural net and n tool-adapted algorithms and functions were tested in this analysis Standardization of data helps with quick testing and lower prediction error. Before the preparation and the testing, the input and output data is normalized by converting the data to 0–1 using the Equation below:

$$X\hat{}= \frac{X - X_{MIN}}{X_{Max} - X_{MIN}} \quad .. (2)$$

Equation used for actual value after competition of neural network is as under:

$$X = X^*(X_{Max} - X_{Min}) + X_{MIN} \quad .. (3)$$

Results and Discussion

The ANN adequacy is tested based on R2 errors such as SAR, RSC, MAR, KR and percent Na estimates. RMSE and MARE values are often used as indexes to verify the model's snapping. The application of ANN was examined in order to determine the adequacy of groundwater to irrigate. The 50 observations of the city of Pipar are being investigated.

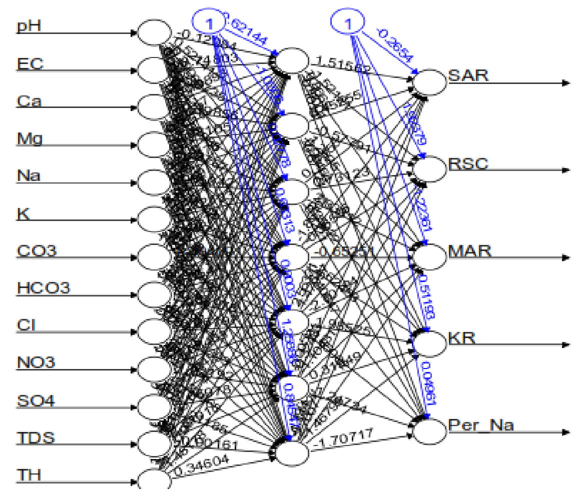

Fig. 4. Optimized ANN model

The prediction of several indexes that reflect the appropriateness of groundwater to be irrigated has been selected as input parameters for all physiochemical variables such as pH, EC, TDS, Ca, Mg, Na, K, Cl, CO3, HCO3, SO4 and NO3. MLP precision is used and the ANN model findings are summarized in Table 3. Statistics outputs are evaluated and shown in Table 2.

Where Min refer to Minimum, Max refer to Maximum, SD refer to standard deviation, SE refer to standard error, Kur refer to kurtosis, Skew refer to skewness and R refer to Range. All values expressed in mg/L except pH and EC.

SAR is an effective ratio for determining irrigation water compatibility. It tests calcium and magnesium levels of sodium in water. The sodium surplus is dangerous to the plant because of its reinforcing effects which influence the soil permeability. Compatible distribution as seen in the spatial distribution chart (Fig. 5a to Fig. 5e) of expected and observed SAR values. The seven neurons demonstrate the least variance in the estimation of competency variables for groundwater irrigation is found. The accumulation of carbonate and bicarbonate on calcium and magnesium ions is evaluated by an RSC ratio for soil permeability. Calcium and magnesium are precipitated by carbonate and bicarbonate ions. Positive RSC value shows that sodium developed can influence the permeability of the soil. The sodium ratio for calcium and magnesium is used to determine sodium content. The high sodium presence will adversely affect the soil. Table 5 confirms that the mean KR values estimated and forecasted are identical, but the spatial distribution variations are evident in Fig. 5a - Fig. 5e.

Table 3. The reliability of the developed Neural network for forecasting different irrigation water adequacy indexes

Output	R^2	RMSE	MARE
SAR	0.987	0.16	13.45
RSC	0.998	0.17	9.45
MAR	0.997	0.15	14.45
KR	0.996	0.2	13.76
%Na	0.994	0.10	9.543

Table 4. Assessment of prediction outputs (viaMS Excel)

Output	R^2	RMSE	MARE
SAR	0.97	0.21	31.78
RSC	1	0.00	0.24
MAR	0.93	16.97	5.89
KR	0.91	0.12	35.89
%Na	0.97	10.87	5.43

Table 2. Descriptive statistics of physicochemical variables

Variables	Mean	Min	Max	SD	SE	Kur.	Skew.	R
pH	7.23	7.03	7.75	0.16	0.02	-0.73	-0.07	0.68
EC	4321.34	881.45	63,889	13111.77	1856	14.66	3.96	65,345
Ca	41.21	11.11	100.89	20.94	2.93	1.11	0.98	90.04
Mg	31.25	9.04	60.87	11.66	1.66	-0.01	0.07	52.45
Na	100.35	28.56	313.56	70.77	10.55	0.55	1.05	285.66
K	2.23	1.33	3.89	0.66	0.07	0.08	-0.07	2.55
CO3	16.54	0	60	12.44	1.78	1.57	0.88	60
HCO3	178.30	78	470	77.67	11.06	5.07	1.95	389
CL	166.32	58.56	495.78	81.34	11.57	5.15	1.92	434
NO3	3.32	0.11	7.10	1.74	0.21	-0.74	-0.13	7
SO4	13	3.11	37.44	7.55	1.03	0.45	0.81	34
TDS	583.23	337.45	1207.44	185.44	25.31	3.03	1.66	870.67
TH	243.25	98.21	425.55	70.55	10.44	0.06	0	325.55

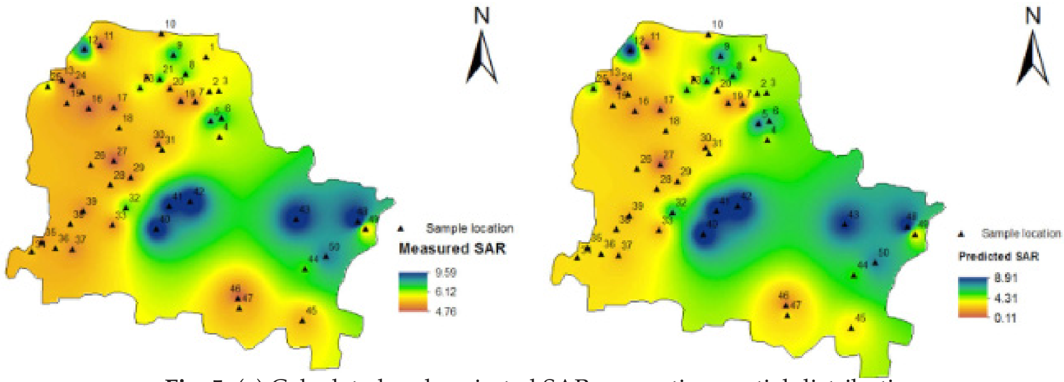

Fig. 5. (a) Calculated and projected SAR proportion spatial distribution

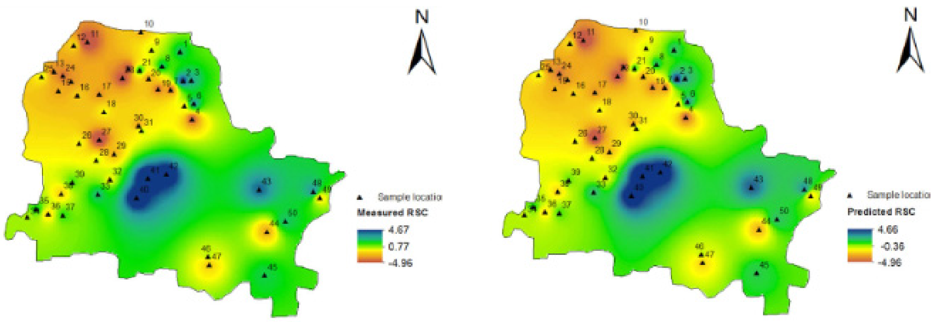

Fig. 5. (b) Calculated and projected RSC proportion spatial distribution

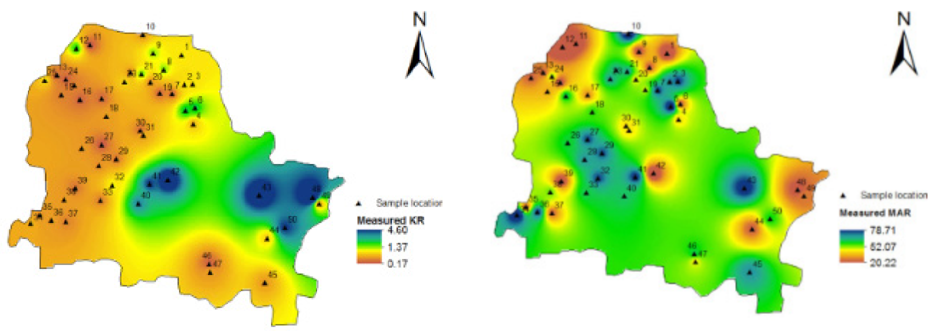

Fig. 5. (c) Calculated and projected MAR proportion spatial distribution

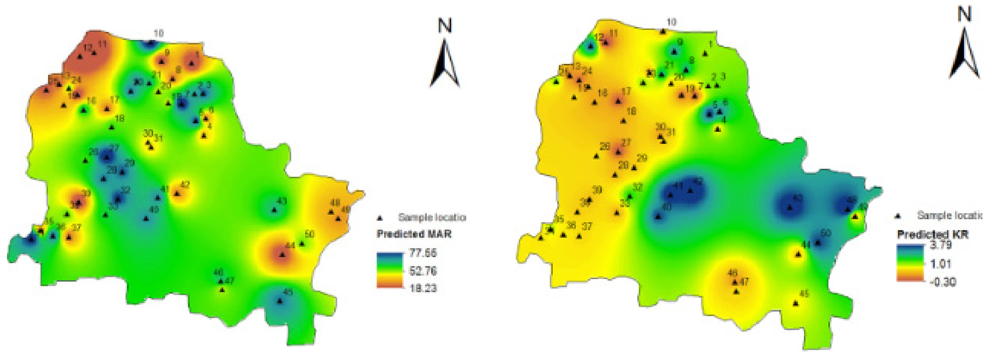

Fig. 5. (d) Calculated and projected KR proportion spatial distribution

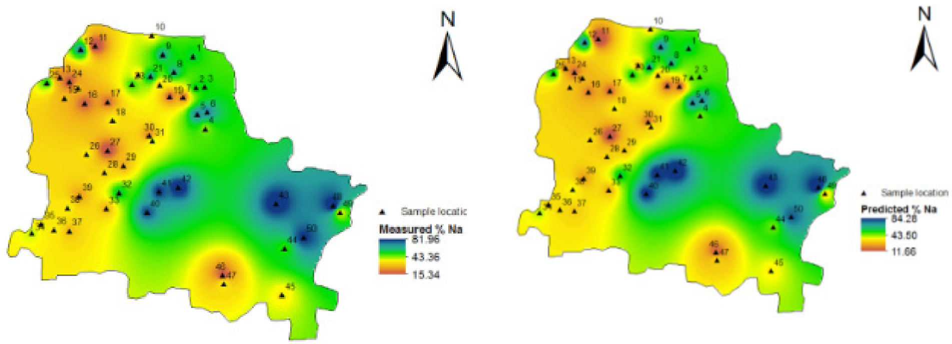

Fig. 5. (e) Calculated and projected %Na proportion spatial distribution

Table 5. Statistics outputs of calculated and forecasted irrigation water suitability variables

Parameter	Measured					Predicted				
	SAR	RSC	KR	MAR	%Na	SAR	RSC	KR	MAR	%Na
Min	0.66	-4.68	0.12	20.44	15.05	0.06	-4.55	-0.33	18.33	11.88
Max	9.56	4.55	4.77	77.99	82.44	7.87	4.88	3.96	77.94	85.88
Average	3.56	-1.21	1.19	56	44.98	3.32	-1.44	1.10	56	46.88
SD	2.67	2.08	1.09	14.99	17	2.34	2.07	1.01	13.54	17.81

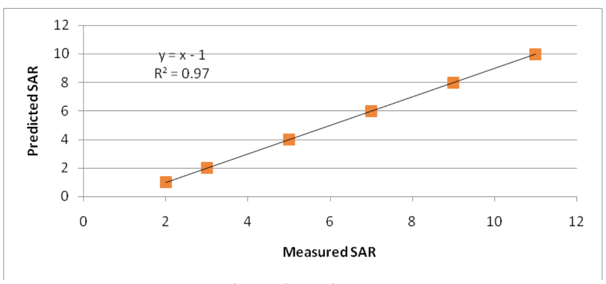

Fig. 6. Predicted and Measure SAR

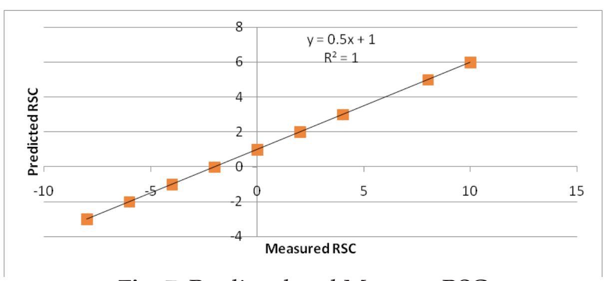

Fig. 7. Predicted and Measure RSC

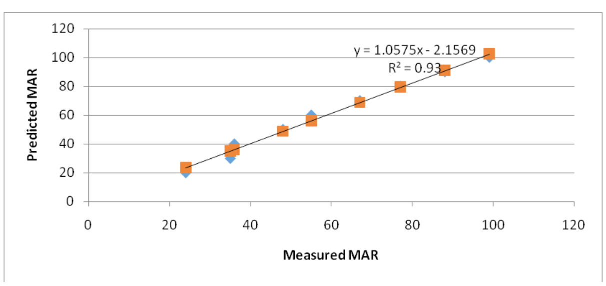

Fig. 8. Predicted and Measure MAR

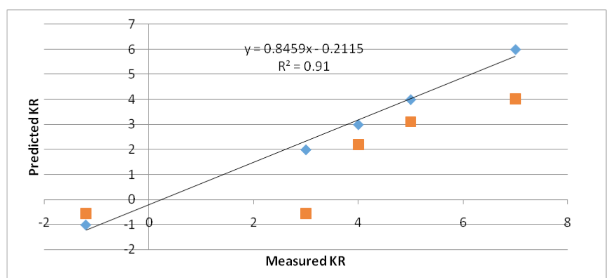

Fig. 9. Predicted and Measure KR

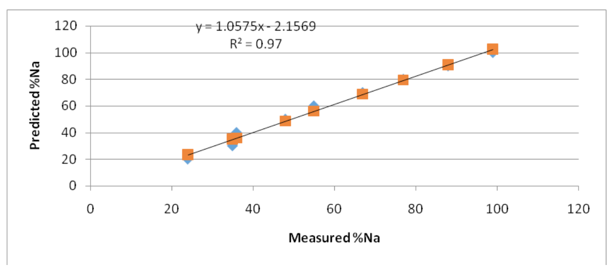

Fig. 10. Predicted and Measure %Na

Conclusion

This study shows that, in 50 observations in pipar region, ANN gives a clear approach for evaluating SAR, RSC, MAR, KR and percent Na. For calculating the adequacy of ground water for irrigation in the pipar region under analysis, a neural network model comprising 13 input neurons, 7 hidden neurons and 5 output variables was utilized. Owing to the heavy use of chemical fertilizers, the SAR, MAR and KR values increase. In comparison with the SAR, MAR and KR values, the RSC and the Na percentage were found to be more precise according to RMSE, R^2 and MARE values. In the input variables used for simulation, EC was the most important parameter. In 50 observations, the suggested framework was adequate for the dataset collected experimentally. Association among the diverse irrigation index calculated through ANN and MS-Excel shows that the property of groundwater irrigation is determined by enhancing the precision. The spatial maps distributions reveal the precision of the observed and expected values. The suggested ANN model is thus valid in a simpler way to calculate the adequacy of ground water for irrigation.

Ethical Approval: This study follows all ethical practices during writing.
Consent to participate: Not applicable.
Consent to publish: Applicable

Authorship Contribution

Sangeeta Parihar: Methodology, Conceptualization, Supervision.
Jai Singh Kachhwaha: Writing - review & editing
Poonam Poonia: Validation, Data curation
Tarun Gehlot: Investigation, Visualization.
Krishan Kumar Saini: Resources, Project administration.
Funding: No Funding Received from any sources
Competing interests: The authors declare no competing interests.
Availability of data and materials: Research Data of this paper could be provided and will be available whenever required so. The current specific data can be made available upon request.
Transparency: The authors confirms that the manuscript is an honest, accurate, and transparent account of the study was reported; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained.

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