WATER DEMAND PREDICTION IN AGRICULTURE, CONSTRUCTION INDUSTRY, AND RESIDENTIAL SECTORS USING MACHINE LEARNING MODEL RELYING ON KNOWLEDGE MANAGEMENT CONCEPT

PREVISÃO DA DEMANDA DE ÁGUA NOS SETORES AGRÍCOLA, DA CONSTRUÇÃO CIVIL E RESIDENCIAL UTILIZANDO UM MODELO DE APRENDIZADO DE MÁQUINA BASEADO NO CONCEITO DE GESTÃO DO CONHECIMENTO

PREDICCIÓN DE LA DEMANDA DE AGUA EN LOS SECTORES AGRÍCOLA, DE LA CONSTRUCCIÓN Y RESIDENCIAL MEDIANTE UN MODELO DE APRENDIZAJE AUTOMÁTICO BASADO EN EL CONCEPTO DE GESTIÓN DEL CONOCIMIENTO

Zeinab Abdallah Mohammed Elhassan
ORCID 0009-0004-2652-4109

Department of Architecture
Prince Sultan University
Riyadh Saudi Arabia

Nahla M. Shannan
ORCID 0000-0003-2037-7748

Program in Electronics and Telecommunications Engineering Technology, Applied College
University of Hail
Hail, Saudi Arabia

Faizah Mohammed Bashir
ORCID 0000-0001-7662-5347

Department of Decoration and Interior Design Engineering
University of Hail
Hail, Saudi Arabia

Samuel Moveh*
ORCID 0000-0002-5501-0041

Engineering Faculty
Transport and Telecommunication Institute
Riga, Latvia
moveh.s@tsi.lv

Ali Hussain Alhamami
ORCID 0000-0002-8665-2485

Department of Civil Engineering
College of Engineering
Najran University
Najran, Saudi Arabia

Taha Gammoudi
ORCID 0009-0008-5505-7895

Department of Fine Arts
University of Hail
Hail, Saudi Arabia

Mohamed Ahmed Said Mohamed
ORCID 0000-0002-7987-0986

Department of Architectural Engineering
University of Hail
Hail, Kingdom of Saudi Arabia
College of Architecture
Sudan University of Science and Technology
Khartoum, Sudan

Abstract. In contemporary times, the focus of water resource management has shifted from constructing novel water supply systems to the proficient management and utilization of pre-existing systems. Knowledge management is one of the most powerful tools in management science, which is very useful for identifying experimental solutions to this issue. Owing to the fact that machine learning techniques provide ideas for predicting complex phenomena, this study employed the ANFIS model to predict water demand in agriculture, construction, and residential sectors in Mecca Province, Saudi Arabia. Data spanning from 2000 to 2021 was utilized for this purpose. To achieve enough data, the Diz method is utilized for the seasonalization of annual data. The present study assessed and compared the efficacy of water recycling as a means to enhance productivity in the agriculture, construction, and residential sectors in response to water demand management. The findings indicate that the implementation of a water management and recycling strategy can potentially lead to a reduction of 4%, 6%, and 0.8% in water consumption by the agriculture, construction, and residential sectors respectively, by the year 2025. In the absence of management techniques and productivity measures

Br. J. Ed. Tech. Soc, v.17, n.se4, p.190-205, 2024
DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

aligned with projected water demand in 2025, the annual consumption levels for the agriculture, construction, and residential sectors are estimated to increase by 20.0, 0.5, and 1.0 MCM, respectively.

Keywords: Knowledge Management, Machine Learning, Construction; Agriculture, Residential, Water Demand, Water Recycling, Productivity.

Resumo. Nos tempos contemporâneos, o foco da gestão de recursos hídricos mudou de construir novos sistemas de abastecimento de água para a gestão e utilização eficiente dos sistemas já existentes. A gestão do conhecimento é uma das ferramentas mais poderosas na ciência da gestão, sendo extremamente útil para identificar soluções experimentais para essa questão. Considerando que as técnicas de aprendizado de máquina fornecem ideias para prever fenômenos complexos, este estudo empregou o modelo ANFIS para prever a demanda de água nos setores agrícola, da construção civil e residencial na Província de Meca, na Arábia Saudita. Foram utilizados dados de 2000 a 2021 para esse propósito. Para alcançar uma quantidade suficiente de dados, o método Diz foi utilizado para a sazonalização dos dados anuais. O presente estudo avaliou e comparou a eficácia da reciclagem de água como uma forma de aumentar a produtividade nos setores agrícola, da construção civil e residencial em resposta à gestão da demanda de água. Os resultados indicam que a implementação de uma estratégia de gestão e reciclagem de água pode potencialmente levar a uma redução de 4%, 6% e 0,8% no consumo de água pelos setores agrícola, da construção civil e residencial, respectivamente, até o ano de 2025. Na ausência de técnicas de gestão e medidas de produtividade alinhadas com a demanda projetada para 2025, os níveis de consumo anual para os setores agrícola, da construção civil e residencial devem aumentar em 20,0, 0,5 e 1,0 MCM, respectivamente.

Palavras-chave: Gestão do conhecimento, aprendizado de máquina, construção civil, agricultura, residencial, demanda de água, reciclagem de água, produtividade.

Resumen. En la actualidad, el enfoque de la gestión de los recursos hídricos ha pasado de la construcción de nuevos sistemas de suministro de agua a la gestión y utilización eficientes de los sistemas preexistentes. La gestión del conocimiento es una de las herramientas más poderosas de la ciencia de la gestión, que resulta muy útil para identificar soluciones experimentales a este problema. Debido a que las técnicas de aprendizaje automático proporcionan ideas para predecir fenómenos complejos, este estudio empleó el modelo ANFIS para predecir la demanda de agua en los sectores agrícola, de la construcción y residencial en la provincia de La Meca, Arabia Saudita. Para este propósito, se utilizaron datos que abarcan desde 2000 hasta 2021. Para obtener datos suficientes, se utiliza el método Diz para la estacionalización de los datos anuales. El presente estudio evaluó y comparó la eficacia del reciclaje de agua como medio para mejorar la productividad en los sectores agrícola, de la construcción y residencial en respuesta a la gestión de la demanda de agua. Los hallazgos indican que la implementación de una estrategia de gestión y reciclaje del agua puede conducir potencialmente a una reducción del 4%, 6% y 0,8% en el consumo de agua en los sectores agrícola, de la construcción y residencial respectivamente, para el año 2025. En ausencia de técnicas de gestión y medidas de productividad alineadas con la demanda de agua proyectada en 2025, se estima que los niveles de consumo anual para los sectores agrícola, de la construcción y residencial aumentarán en 20,0, 0,5 y 1,0 MCM, respectivamente.

Palabras-clave: Gestión del conocimiento, aprendizaje automático, construcción, agricultura, residencial, demanda de agua, reciclaje de agua, productividad.

1. INTRODUCTION

The scarcity and contamination of water resources, coupled with a rapid increase in water demand, has resulted in a global water crisis (Sun & Scanlon, 2019). Water, being a valuable natural resource, is a fundamental human necessity and a national asset for societies (Sit et al., 2020). Furthermore, a significant proportion of the world's water resources are saline in nature, leaving only a mere three percent of freshwater available for consumption (Feldman & Ingram, 2009). Therefore, judicious and rational distribution of water resources is imperative for ensuring their sustainable utilization (Pallathadka et al., 2023).

The forthcoming impacts of climate change on water resources will bring to the forefront the issue of water scarcity. Hence, the escalation of water scarcity in arid and semi-arid territories globally, including North Africa, the Middle East, and Asia, is a foreseeable occurrence (Seyedzadeh et al., 2018). According to Mekonnen et al. (2019) the distribution of water resources in China exhibits non-uniformity, resulting in varying levels of rainfall across different regions of the country. Saudi Arabia is considered to be a region with arid and harmonious conditions due to its geographical location and desert strip situated between 2 to 5 degrees North latitude (Kouadri et al., 2021).

The quantity and distribution of precipitation during the humid seasons exhibit considerable variability on an annual basis (Alanne & Sierla, 2022). This variability, coupled with recurrent droughts, has intensified the water crisis, affecting nearly all regions of the country and consequently influencing water consumption patterns (Abbasi et al., 2022).

In light of the significance of this issue, it appears imperative to strategize for the most efficient utilization of water (Ison et al., 2007). The initial step towards the efficient allocation of water resources is the assessment of water demand. The objective of this process is to infer the future water demand based on historical usage, current conditions, and environmental variations.

The demand for water is typically influenced by a range of factors, including but not limited to population, water availability, climate conditions, environmental considerations, and economic factors (Arnell, 2024). Various policies have been implemented to address the issue of mismanagement and suboptimal utilization of water resources across various sectors. These policies have led to the development of a diverse array of solutions aimed at managing water access and demand. The policies encompass various aspects such as water specialization, water transfer, concurrent utilization of groundwater and surface water, groundwater storage, wastewater recycling and reuse, seawater desalination, enhancement of water use efficiency, implementation of water conservation technologies, modification of product composition, regulation of minimum environmental flow, and utilization of economic instruments such as pricing and water traders, which also involves procuring water for environmental objectives (Bakker, 2005).

Hence, it is imperative to identify, prioritize and implement measures aimed at preventing water shortages, while simultaneously adopting planned adjustment measures. Nevertheless, the implementation of these measures and strategies necessitates the acquisition of relevant information. The objective of current and future forecasting is to anticipate various outcomes for anticipated circumstances, utilizing a comprehensive and effective model.

Construction and its associated activities may be regarded as one of the most environmentally taxing and contaminating human endeavors. During the construction process and material production, a substantial quantity of carbon is emitted and water is utilized, both of which hold considerable significance and cannot be disregarded. The manufacture of construction materials entails significant consumption of energy and water, ultimately depleting non-renewable natural resources.

The generation of hazardous environmental contaminants and the overconsumption of water in the construction sector have been a persistent concern, regardless of the intended purpose of a given building (Carroon, 2010). This issue arises during the construction phase,

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

as well as during the operational and demolition phases. Hence, it is imperative to prioritize the meticulous consideration of the design, construction, and operation of edifices in order to curtail the emission of environmental contaminants, in alignment with the objectives of sustainable development.

Empirical evidence suggests that the fuzzy inference system exhibits superior performance in evaluation water demand models owing to its ability to incorporate uncertainty and align with real-world scenarios. The successful outcomes and proficient performance of the fuzzy inference system in the domain of water demand estimation have prompted the integration of the fuzzy inference system with the artificial neural network, referred to as Adaptive Neuro-Fuzzy Inference System (ANFIS). The ANFIS model is founded upon the neural network learning algorithm, while the Fuzzy arc employs a non-linear mapping approach between the input and output spaces. The system, in its current form, possesses the linguistic benefits inherent in fuzzy inference systems, as well as the capacity for learning characteristic of neural networks. Thus, it exhibits superior capabilities in contrast to artificial neural networks and fuzzy inference systems.

The efficient utilization of water resources through recycling is a critical aspect of contemporary agricultural and construction industries, wherein knowledge management assumes a pivotal role. The growing need for sustainable practices necessitates the incorporation of knowledge management strategies. Efficient knowledge management can aid in the distribution of information regarding water recycling techniques, including drip irrigation systems and precision farming methods, within the agricultural industry. This allows agricultural practitioners to reduce water loss and optimize agricultural productivity. Likewise, within the realm of construction, the implementation of knowledge management strategies can facilitate the assimilation of water conservation mechanisms, such as greywater recycling and rainwater harvesting.

Through the adoption of these methodologies, construction firms can effectively mitigate their dependence on potable water resources and mitigate the ecological repercussions of their undertakings. Incorporating knowledge management principles and implementing water recycling practices in agriculture and construction are crucial measures for attaining sustainable outcomes in these domains.

Although ANFIS method is one of the powerful methods in econometrics, it has not been given much attention. In the same direction, in the present research, the modeling and forecasting of water demand in agriculture, construction and residential sectors for Mecca province has been addressed, and the period related to modeling is from 2000 to 2021. Looking forward to 2021 Until 2025, it will be annual and seasonal.

The difference between the present study and other studies in society is the use of knowledge management in increasing the efficiency of using water resources. In the second section of the research, the method used in this research is described in detail. The section 3 includes the results and forecast of water demand in Mecca province, and finally, the general conclusion of the research is presented in section 4.

2. MATERIALS AND METHODS

The research model and the evaluation tests that were used in this study are described in this section. The present study employs the ANFIS model to forecast water demand in Mecca province, Saudi Arabia up to 2025. Meanwhile, the knowledge management scenario for water management was applied to evaluate the effect of recycle water use on water demand in future. The model's structure and formulation are explicated in the following.

2.1. Fuzzy inference system

The utilization of water demand prediction serves as an input-output dataset for the calibration of fuzzy rules in a fuzzy inference system. The fuzzy inference model establishes a relationship between the inputs, which includes the available volume of water reserves and consumption, Population, area of cultivated land, number of industrial units, number of structures under construction, and the output, which includes the amount of water demand, through the use of fuzzy if-then rules. Thus, the process of decision-making occurs in two distinct phases.

The initial stage involves the application of a fuzzification process to the input and output variables, which can be achieved through the utilization of membership functions, including but not limited to triangular or trapezoidal functions. During the second phase, the input variables are aggregated to generate fuzzy rules utilizing the standard operators "and," "or," and "without," with uniform weighting across all rules.

The process of mapping input to output in fuzzy inference systems can be accomplished through two distinct models: the Sugeno Fuzzy Model and the Mamdani Fuzzy Model. The Mamdani fuzzy inference model operates on the basis of fuzzy principles and produces output accordingly. This implies that it is a mathematical function. The resultant membership is a fuzzy set as well.

Conversely, Sogino fuzzy systems exhibit output membership functions that are both linear and constant. In the Sogino approach, the process of de-fuzzification is attributed to the feasibility of achieving flexibility and stability through constrained methodologies. Consequently, the Mamdani fuzzy inference system was employed in this investigation.

2.2. Adaptive Neuro-Fuzzy Inference System

This type of network is formed through the amalgamation of artificial neural networks and fuzzy logic, enabling it to comprehend imprecise rules. Additionally, fuzzy logic encompasses the distinctive parameters of the artificial neural network. The ANFIS, which stands for adaptive neural network based on fuzzy inference system, has been found to possess superior capabilities in comparison to artificial neural networks and fuzzy logic. This is the ultimate conclusion drawn from the analysis. The ANFIS system is a network-based implementation of a Sogno-type fuzzy system. The second figure illustrates a Sogno fuzzy system that comprises two input variables, one output variable, and two governing rules.

Inputs are depicted in Figure 1 as A, B, C, and D. The output of the system, represented by WD, corresponds to the volume of water demand at time t+1. The legal framework of this particular system can also be articulated through the utilization of Equations 1 and 2 [34].

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

If A is A_1& B is B_1& C is C_1 & D is D_1 (1)

then $\mathrm{WD} = \mathrm{p_1 A} + \mathrm{q_1 B} + \mathrm{k_1 C} + \mathrm{r_1} D + \mathrm{m_1}$

If A is A_2& B is B_2& C is C_2 & D is D_2 (2)

then $\mathrm{WD} = \mathrm{p_2 A} + \mathrm{q_2 B} + \mathrm{k_2 C} + \mathrm{r_2} D + \mathrm{m_2}$

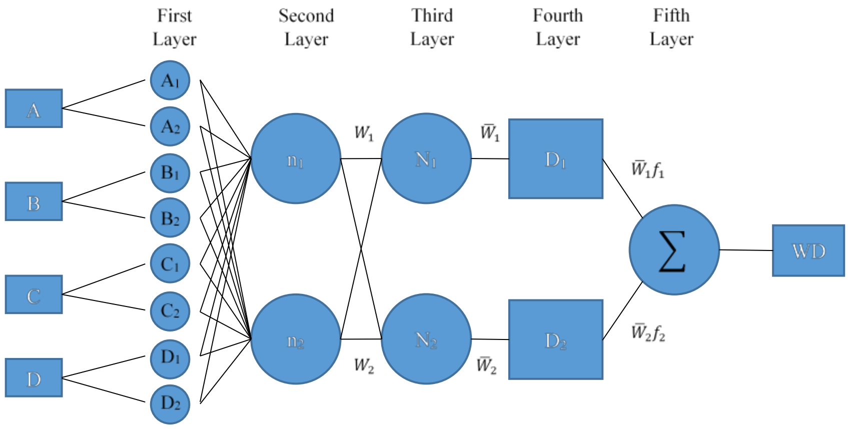

Figure 1. A scheme of the ANFIS model

As depicted in Figure 1, the ANFIS network architecture comprises five distinct layers. The initial stratum is referred to as the input layer, wherein each node is representative of a fuzzy set. The output of each node corresponds to the degree of membership of the variable in the input set. The parameters in question exhibit a degree of imprecision. The shape of the membership function of a fuzzy set is determined by each individual node. The design of neural-fuzzy networks involves the utilization of diverse functions such as triangles, trapezoids, bells, among others.

In the subsequent layer, the input parameters assigned to each individual node undergo a multiplication process, resulting in the derivation of the weight of the regulations. Equation 3 depicts the degree of activity of a law, which is calculated by each node in the second layer.

$$\mathrm{Q_i^2} = \mathrm{w_i} = \mu_{\mathrm{Ai}}(\mathrm{x}) \times \mu_{\mathrm{Bi}}(\mathrm{y}) \tag{3}$$

With respect to Equation 3, the variable μ_Ai (x) denotes the degree of membership of x in the set Ai, while the variable μ_Bi (y) represents the degree of membership of y in the set Bi. The nodes assume a significant function in the third layer. The entities comprising this stratum are the proportional magnitudes assigned to the regulations.

Through utilization of Equation 4, it becomes feasible to compute the proportionate weight of the i-th node in relation to the aggregate weight of the corresponding layer.

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

$$Q_i^3 = \bar{w}_i = \frac{w_i}{w_1 + w_2}, \; i = 1{,}2 \tag{4}$$

where wi represents the level of legal weight associated with the activity i-th. At the fourth layer, the output of every node is expressed in the format of Equation 5:

$$Q_i^4 = \bar{w}_i f_i = \bar{w}_i \cdot (p_i A + q_i B + k_i C + r_i D + m_i), \; i = 1{,}2 \tag{5}$$

The consequent parameters of this layer are denoted as {pi, qi, ri} and are utilized as application parameters.

The output layer of ANFIS is represented by the fifth layer. Every individual node within this particular layer performs computations to derive the ultimate output value, which is expressed in the format of Equation 7.

In this particular stratum, the quantity of nodes is commensurate with the quantity of outputs, resulting in a value of one in the majority of research endeavors. The utilization of a linear membership function is being considered. Utilize the concepts of linearity and constancy.

$$Q_i^5 = \sum \bar{w}_n f_i = \frac{\sum w_i f_i}{\sum w_i} \tag{6}$$

Finally, the total output can be expressed as a linear combination of the resulting parameters according to the Equation 8:

$$\begin{aligned} f = \sum \bar{w}_i f_i \quad &= (\bar{w}_1 A)p_1 + (\bar{w}_1 B)q_1 + (\bar{w}_1 C)k_1 + (\bar{w}_1 D)r_{1+}(\bar{w}_1)m_1 \\ &+(\bar{w}_2 A)p_2 + (\bar{w}_2 B)q_2 + (\bar{w}_2 C)k_2 + (\bar{w}_2 D)r_{2+}(\bar{w}_2)m_2 \end{aligned} \tag{7}$$

Typically, in ANFIS network training, two learning algorithms, namely Back Propagation and the Hybrid method, are employed. This research employed both techniques and subsequently juxtaposed the outcomes.

The fuzzy inference system incorporates various inputs such as the volume of reserves and water consumption, population, cultivated land area, number of residential units and structures under construction. The output of the model is the quantification of water demand. The input variables are characterized by five distinct membership functions, namely "very low", "very high", "low", "high", and "medium". On the other hand, the result variable (output from the repository) is represented by seven membership functions, namely "very low", "very high", "low", "high", "relatively high", "relatively low", and "moderate". The upper and lower limits of the "very low" and "very high" membership functions are determined by the maximum and minimum values of each variable.

The diagram depicted in Figure 2-a illustrates the membership functions pertaining to the outcome variable in a state of normalcy. The trapezoidal membership function was employed for the "low" and "high" membership functions, while the "medium" membership function was represented by the triangular function. Figure 2-b, an overview of the fuzzy logic structure used in this study is given.

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

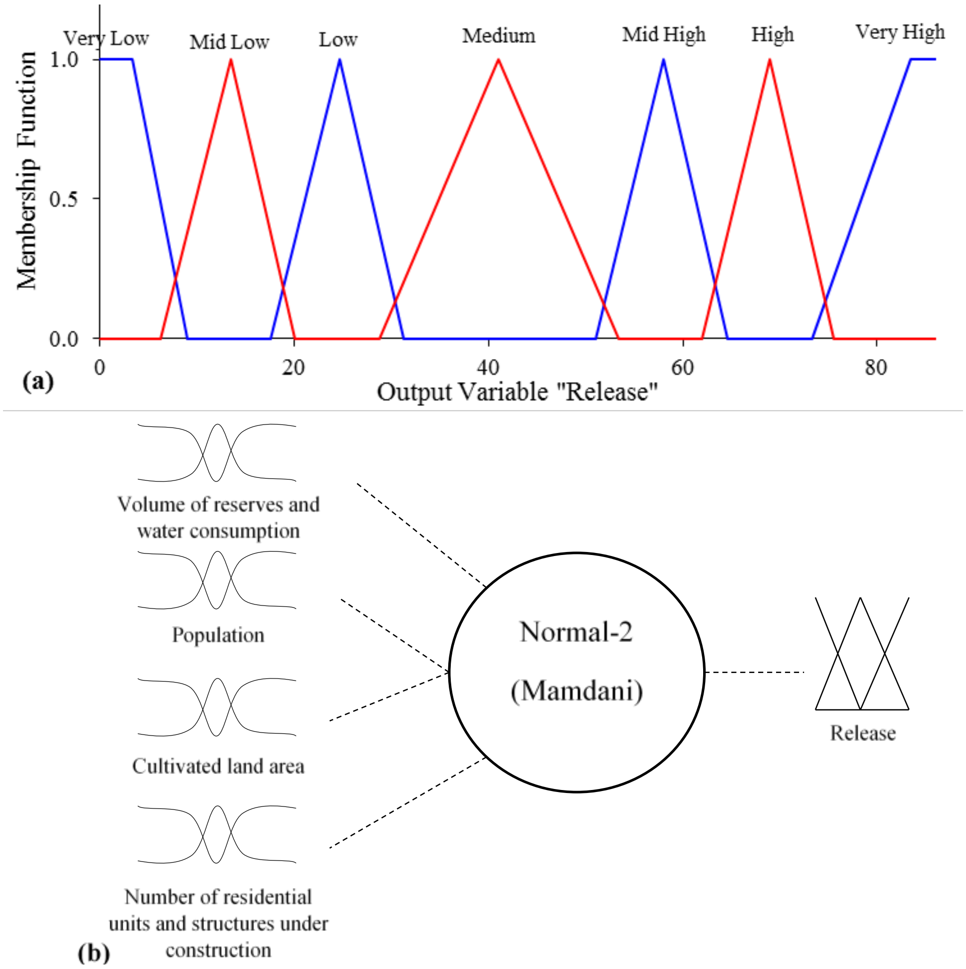

Figure 2. a) Output membership functions of water demand in Mecca province, **b)** An overview of the structure of fuzzy logic of the second model

The present investigation deemed the upper limit of repetitions to be 1000. The evaluation of various ANFIS models revealed that the ANFIS model featuring a single input and output, a bell function in the input, and a linear function in the output exhibited superior performance compared to other designed systems. It is imperative to note that within the scope of this investigation, a distinct ANFIS model was formulated for every calendar year. The training dataset consisted of 80% of the 20-year data, while the remaining 20% was allocated for testing purposes. Python was also used to design, train and test ANFIS.

2.3. Evaluation Criteria

To evaluate the predictive efficacy of the models, four criteria are employed, namely: mean squared error (MSE), root mean squared error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE) (Equations 8-11).

$$MSE = \frac{\sum_1^m \left(\hat{Y}_t - Y_t\right)^2}{m} \tag{8}$$

Br. J. Ed. Tech. Soc, v.17, n.se4, p.190-205, 2024
DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

$$RMSE = \sqrt{\frac{\sum_1^m \left(\hat{Y}_t - Y_t\right)^2}{m}} \tag{9}$$

$$MAE = \frac{\sum_1^m \left|\hat{Y}_t - Y_t\right|}{m} \tag{10}$$

$$MPAE = \frac{\sum_1^m \left|\frac{\hat{Y}_t - Y_t}{Y_t}\right|}{m} \tag{11}$$

Given that each of the aforementioned criteria represents a distinct facet of the models' performance, it would be advantageous to employ all of these metrics in order to assess the models and their capacity for prediction. Subsequently, the Diz method is employed to convert the annual data from the research period spanning from 2000 to 2021 into seasonal data.

This approach is utilized to enhance the precision of the models by mitigating the potential issue of absent data. Subsequently, subsequent to estimating the ANFIS model, the outcomes of said estimation will be evaluated in conjunction with the forecasted results.

2.4. Seasonalization of annual data

Insufficient data for conducting linear regression may yield unsatisfactory outcomes in the intended estimation. As the volume of data increases, the level of confidence in the estimation outcomes also rises. Utilizing seasonal data instead of annual data is a viable approach to augment the quantity of data for a given timeframe.

The absence of seasonal data in the majority of national and provincial statistics necessitates the utilization of scientifically valid techniques to seasonally adjust the variables. One of the techniques employed for seasonalizing variables is the Diz method.

At time t, Xt represents a variable. Four distinct values of qi (i = 1, ..., 4) are derived in the format of Equations 12-15.

$$q_1 = X_{t-1} + \frac{7.5}{12}(X_t - X_{t-1}) \tag{12}$$

$$q_2 = X_{t-1} + \frac{10.5}{12}(X_t - X_{t-1}) \tag{13}$$

$$q_3 = X_t + \frac{1.5}{12}(X_{t+1} - X_t) \tag{14}$$

$$q_4 = X_t + \frac{4.5}{12}(X_{t+1} - X_t) \tag{15}$$

The value of variable X in chapter i at time t, which is shown as Xit, is calculated as Equation 16:

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

$$X_{it} = \frac{4X_t}{q_1 + q_2 + q_3 + q_4} \times q_i \tag{16}$$

By using this method, the data related to the third quarter of the first year of the studied period until the second quarter of the last year of the period are obtained. In order to compute the initial and subsequent seasons of the inaugural year, it is imperative to possess the variable quantity from the preceding year.

In the absence of this data, the seasonal variables are estimated by utilizing the trend that governs them. In order to compute the final four years of the curriculum, it is necessary to incorporate the data from the subsequent year. To perform the computation, we follow the same procedure as previously described.

3. RESULTS AND DISCUSSION

The statistical of the Mecca provinces contains annual records of water consumption, albeit for a limited number of years. Consequently, the unavailability of data renders annual data unsuitable for predicting future years. The current investigation utilized the Diz method to convert annual data from the examined time period into seasonal data, providing a viable foundation for future forecasting.

As previously mentioned, this approach was employed in the present study. Table 1 displays the descriptive statistics pertaining to water demand across the agriculture, construction, industry, and household sectors in Mecca province from 2000 to 2021. Descriptive statistics of water demand exhibit normal distribution at a significance level of 0.05.

Table 1. Descriptive statistics of water demand in agriculture, construction and household sector in Mecca province between 2000 and 2021

Index	Sector		
	Agriculture	**Construction**	**Residential**
Average	381.2	4.2	42.4
Maximum	421.5	7.4	66.1
Minimum	310.8	2.7	13.6
Standard Deviation	21.5	0.6	8.1

One of the underlying assumptions that underpins the utilization of conventional econometric techniques for estimating model coefficients from time series data is the presumption of the exogeneity of the variables under investigation. In econometric model estimation, inaccurate variables can result in a spurious or erroneous estimated regression.

The significance of the variables will be assessed through the utilization of unit root tests. The current investigation employed the KPSS test to examine the variables under study, and the outcomes of this test are presented in Table 2.

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

Table 2. KPSS test results

Sector	KPSS	Critical values at different probability levels			Output
		0.01	0.05	0.1	
Agriculture	0.065	0.202	0.112	0.101	I(0)
Construction	0.049	0.202	0.112	0.101	I(0)
Residential	0.057	0.202	0.112	0.101	I(0)

The findings derived from the KPSS unit root analysis presented in Table 2 indicate that the null hypothesis, which posits the non-existence of a unit root for all variables during the period of investigation, has been upheld. Consequently, it can be inferred that all variables are characterized by a state of stability.

3.1. Water Demand Estimation in Agriculture Sector

Figure 3 shows the results of the simulation of water demand of the agricultural sector for Mecca province. The diagrams are bifurcated into two distinct sections, with the upper portion depicting the outcomes of the training, evaluation, and testing processes. Meanwhile, the lower section showcases the error rate between the simulated values and the actual data. The findings indicate a notable escalation in the water requisites of the agricultural domain in Mecca province, particularly post-2013.

The observed congruity in the patterns denotes the efficacy of the ANFIS model in experimentation. The MSE, RMSE, MAE, and MPAE indices have been determined to be 41.2 MCM, 6.32 MCM, 4.44 MCM, and 1.2, respectively. Utilizing statistical methods would be advantageous in comparing the two approaches employed in the study, thereby yielding a more robust conclusion.

Based on the graphical representation of water demand, it can be observed that there has been a notable surge in the agricultural domain, particularly during the period spanning from 2016 to 2018.

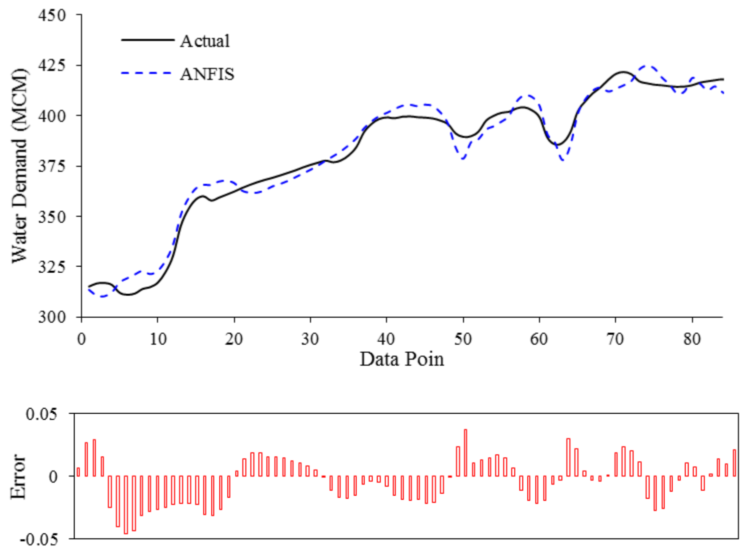

Figure 3. The results of simulating the water demand of the agricultural sector of Mecca province using the ANFIS model

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

The prevailing pattern of water consumption resulting from the arid climatic conditions of the area has the potential to engender numerous challenges for the water provisioning in this domain. Hence, the implementation of knowledge management for the purpose of enhancing productivity is a crucial matter that necessitates the attention of decision-makers to ensure effective management for the sake of sustainable development in this domain in the forthcoming years.

According to Figure 4, the projected water demand for the agricultural industry is expected to persist until the year 2025. Figure 4 indicates that the implementation of knowledge management practices and the utilization of recycled water in the agricultural domain will result in a reduction of approximately 20 MCM of water demand by the year 2025. The aforementioned quantity almost corresponded to the volume of water utilized by the construction sector water demand within the province during the 2016 to 2021.

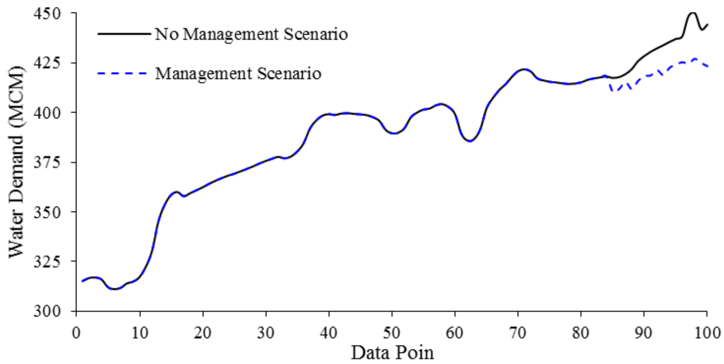

Figure 4. The water demand estimation of the agricultural sector to 2025 of Mecca province by ANFIS model

3.2. Water Demand Estimation in Construction Sector

The efficacy of the ANFIS model in predicting seasonal water demand in the construction industry of Mecca province is demonstrated in Figure 5. The model's performance evaluation indicators demonstrate its efficacy in forecasting water demand within this sector (MSE= 0.129 MCM, RMSE= 0.359 MCM, MAE= 0.30 MCM, and MPAE= 5.1). Nonetheless, the variability in performance and the reduction in water demand during the periods of 2003 to 2006 and 2016 to 2021, attributed to the decline in construction activities within the province, have had an impact on the precision of the model's performance.

The decline in housing construction during the aforementioned period has resulted in a reduction in water consumption during that time. The model's predictive capacity for this component has been challenged owing to the uncertainty associated with its input variable.

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

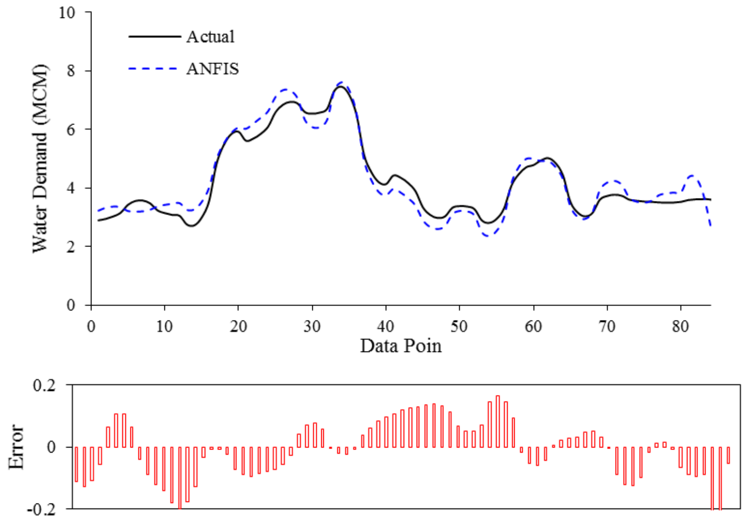

Figure 5. The results of simulating the water demand of the construction sector of Mecca province using the ANFIS model

The water demand forecast until 2025 is presented in Figure 6, depicting two distinct scenarios: the existing scenario and the scenario incorporating recycled water and knowledge management. The graph illustrates that there is variability in water demand, albeit with a downward trajectory. It is important to note that this trend may be subject to modification by macro-level policies, but based on the available data and research inputs, the outcomes remain consistent.

The implementation of knowledge management strategies and the utilization of recycled water in the construction industry can result in a reduction of 0.5 MCM in water demand, as compared to the current scenario. Given the climatic conditions of the locality, significant cost savings can be achieved by implementing this particular solution in the aforementioned region. The adoption of a knowledge management framework and the utilization of recycled water in the construction industry results in a noteworthy reduction in water consumption within this domain.

The management of water consumption in the construction industry is crucial for optimizing productivity, particularly in areas where there is a high level of water waste.

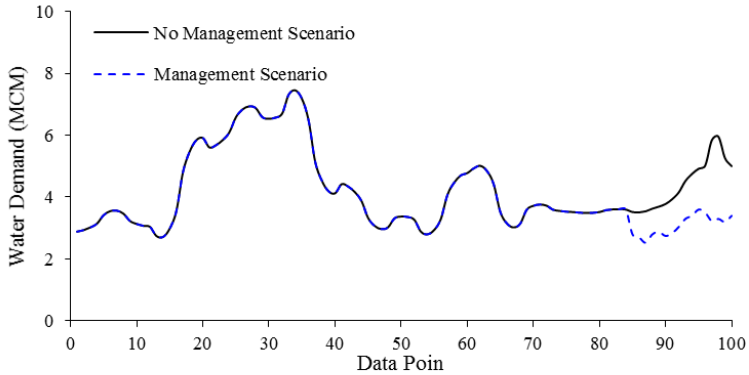

Figure 6. The water demand estimation of the construction sector to 2025 of Mecca province by ANFIS

Br. J. Ed. Tech. Soc, v.17, n.se4, p.190-205, 2024
DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

3.3. Water Demand Estimation in Residential Sector

The utilization of the Mecca water demand through the ANFIS model is depicted in Figure 7. The Model Assessment Index has yielded values of 0.73 MCM, 0.85 MCM, 0.65 MCM, and 1.6 for the MSE, RMSE, MAE, and MPAE indices, respectively. The figure illustrates the upward trend in demand within the residential sector, which can be attributed to the rise in urbanization and population growth.

The per capita demand in this sector has witnessed a notable increase of 12 percent in the year 2021 as compared to the year 2000. The inevitability of employing alternative scenarios arises from the magnitude of water demand.

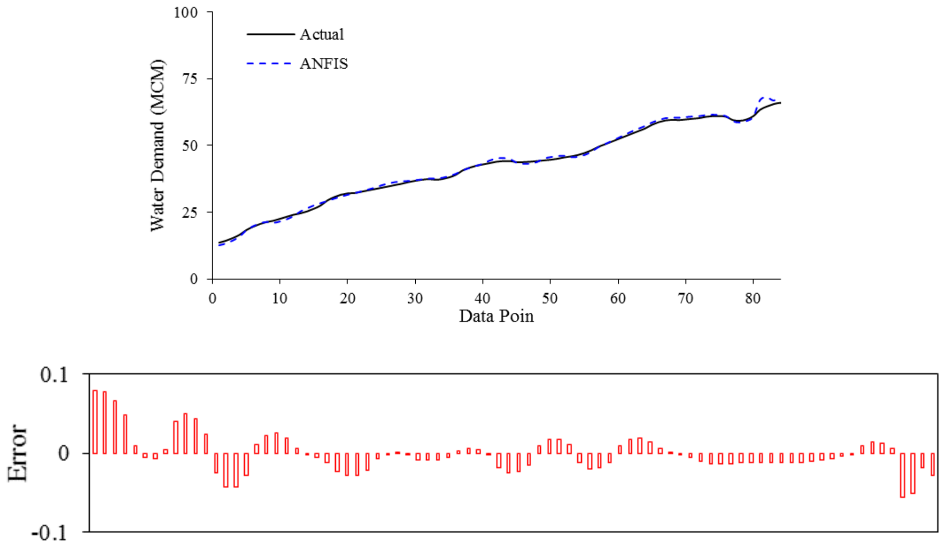

Figure 7. The results of simulating the water demand of the residential sector of Mecca province using the ANFIS model

The investigation of the knowledge management scenario and recycled water use in the home sector was conducted in response to the increasing trend of water demand in this domain. Figure 8 displays the findings of the present investigation. Based on the findings, it can be observed that the Mecca province's water demand process is expected to decrease by 2025.

However, it is noteworthy that the implementation of knowledge management and recycled water utilization in this particular sector is comparatively lower than other sectors. Hence, it is imperative for decision-makers in this domain to undertake research endeavors aimed at curbing water consumption in the forthcoming years, through the adoption of alternative resource management techniques and water consumption practices.

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

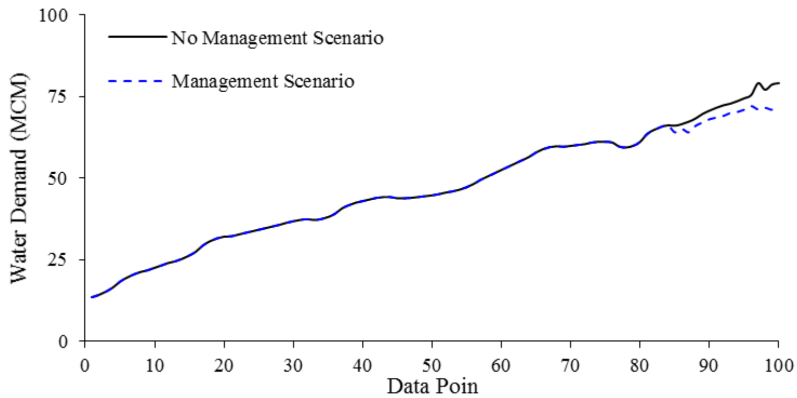

Figure 8. The water demand estimation of the residential sector to 2025 of Mecca province by ANFIS model

4. CONCLUSION

The goal of this study was to forecast the water demand of the agricultural, construction, and domestic sectors in Mecca province from 2000 to 2025, and to that end, the ANFIS model and seasonal data using the Diz method were used from 2000 to 2021. The unit root test was performed on the variables in the first step to ensure that the modeling was not false, and the results showed that all of the variables were significant at the 5% confidence level, indicating that the prediction results are reliable.

When the efficiency of ANFIS-developed water demand models was compared to measures of MSE, RMSE, MAE, and MAPE. It was discovered that water demand modeling in the sector was inefficient. The ANFIS method performed well in Mecca province during the study period, though due to uncertainty in the amount of government attention paid to the construction sector, the evaluation criteria for this sector are weaker than those for the agricultural and residential sectors.

Based on agricultural demand increased significantly from 2016 to 2018. Owing to the area's arid climate, water provisioning may face many challenges. Thus, decision-makers must focus on knowledge management to boost productivity for sustainable development in this field in the future. Recycled water use in agriculture will reduce water demand by 20 MCM by 2025.

The reduction was made in water demand during 2003-2006 and 2016-2021, owing to the province's construction slowdown. Due to input variable uncertainty, this component's predictive power has been challenged. The results show that water demand fluctuating downward. This trend may be affected by macro-level policies. Knowledge management and recycled water use in construction can reduce water demand by 0.5 MCM.

Urbanization and population growth have driven residential demand up in Mecca Province. This sector's per capita demand rose 12% from 2000 to 2021. Due to rising water demand in the residential sector, the knowledge management scenario and recycled water use were investigated. However, this solution has less effect on water demand reduction. Thus, decision-makers in this field must conduct research on alternative resource management and water consumption practices to reduce water consumption in the future.

DOI http://dx.doi.org/10.14571/brajets.v17.nse4.190-205
ISSN 2316-9907

The researchers experienced certain constraints in the course of conducting this study. An identified limitation pertains to incomplete access to the entire set of statistical data throughout the duration of the research. Furthermore, there were complexities encountered during the investigation of this matter that precluded their incorporation into research models. One aspect worth noting is the impact of government decisions on the progress of construction and agriculture. Failure to consider such decisions may potentially obscure the overall findings of the research.

Efforts have been made to incorporate all entries in the study with a high degree of confidence in their accuracy. It is recommended to undertake further investigations utilizing alternative methodologies within the realm of knowledge management, with the aim of enhancing efficiency in the administration of water resources in Mecca province. These studies should be juxtaposed with the findings of the present research.

ACKNOWLEDGMENTS

This research has been funded by Scientific Research Deanship at University of Ha'il, Saudi Arabia through project number RG-20 220

REFERENCES

Abbasi, R., Martinez, P., & Ahmad, R. (2022). The digitization of agricultural industry–a systematic literature review on agriculture 4.0. Smart Agricultural Technology, 2, 100042.

Alanne, K., & Sierla, S. (2022). An overview of machine learning applications for smart buildings. Sustainable Cities and Society, 76, 103445.

Arnell, N. W. (2004). Climate change and global water resources: SRES emissions and socio-economic scenarios. Global environmental change, 14(1), 31-52.

Bakker, K. (2005). Neoliberalizing nature? Market environmentalism in water supply in England and Wales. Annals of the association of American Geographers, 95(3), 542-565.

Carroon, J. (2010). Sustainable preservation: Greening existing buildings. John Wiley & Sons.

Feldman, D. L., & Ingram, H. M. (2009). Making science useful to decision makers: climate forecasts, water management, and knowledge networks. Weather, Climate, and Society, 1(1), 9-21.

Ison, R., Röling, N., & Watson, D. (2007). Challenges to science and society in the sustainable management and use of water: investigating the role of social learning. Environmental science & policy, 10(6), 499-511.

Kouadri, S., Elbeltagi, A., Islam, A. R. M. T., & Kateb, S. (2021). Performance of machine learning methods in predicting water quality index based on irregular data set: application on Illizi region (Algerian southeast). Applied Water Science, 11(12), 190.

Mekonnen, Y., Namuduri, S., Burton, L., Sarwat, A., & Bhansali, S. (2019). Machine learning techniques in wireless sensor network based precision agriculture. Journal of the Electrochemical Society, 167(3), 037522.

Pallathadka, H., Mustafa, M., Sanchez, D. T., Sajja, G. S., Gour, S., & Naved, M. (2023). Impact of machine learning on management, healthcare and agriculture. Materials Today: Proceedings, 80, 2803-2806.

Seyedzadeh, S., Rahimian, F. P., Glesk, I., & Roper, M. (2018). Machine learning for estimation of building energy consumption and performance: a review. Visualization in Engineering, 6, 1-20.

Sit, M., Demiray, B. Z., Xiang, Z., Ewing, G. J., Sermet, Y., & Demir, I. (2020). A comprehensive review of deep learning applications in hydrology and water resources. Water Science and Technology, 82(12), 2635-2670.

Sun, A. Y., & Scanlon, B. R. (2019). How can Big Data and machine learning benefit environment and water management: a survey of methods, applications, and future directions. Environmental Research Letters, 14(7), 073001.