Neutrosophic Systems with Applications, Vol. 1, 2023
https://doi.org/10.61356/j.nswa.2023.4

An Integrated Neutrosophic Regional Management Ranking Method for Agricultural Water Management

Ahmed Abdel-Monem [1], Nada A.Nabeeh [2,*] and Mohamed Abouhawwash [3]

[1] Faculty of Computers and Informatics, Zagazig University, Zagazig 44519, Sharqiyah, Egypt; aabdelmonem@fci.zu.edu.eg
[2] Information Systems Department, Faculty of Computers and Information Sciences, Mansoura University, Dakahlia, 35516, Egypt; nadaadel@mans.edu.eg.
[3] Department of Computational Mathematics, Science, and Engineering (CMSE), College of Engineering, Michigan State University, East Lansing, MI 48824, USA; abouhaww@msu.edu.

* Correspondence: nadaadel@mans.edu.eg.

Abstract: The development of global warming adaptation principles is a crucial issue to resilience to climate change. Due to the consequences of global warming on land and water management. The persistence to determine the adaptation procedures is a demanded challenging process corresponding to the current climate change issues. Climate change has a direct impact on the water cycle that results in unpredictable cases of pollution and rare of water. In order to provide viable options for enormous-scale water supply structures, the study presents a new planning approach that incorporates multi-criteria decision-making (MCDM). The agriculture water management (AWM) relies on MCDM with various criteria and alternatives. The study ranks regional management alternatives with respect to groundwater resources. In addition, study adopts neutrosophic theory to handle unpredictable cases. The proposed decision-making approach integrates neutrosophic sets with the MARCOS method for achieving optimal solutions. A detailed numerical case study that illustrates eight criteria and ten alternatives to examine the applicability for the proposed method.

Keywords: Agriculture Water Management; Global Warming; Climate Change Neutrosophic sets; MCDM; MARCOS Method.

1. Introduction

Climate change pose to challenges and risks on the financial systems and industries [1]. The manufacturing, agriculture, water supplies, and ecology have a direct relation with any catastrophes of climate impact related financial risks. The population inflation and climate change are susceptible to water shortages and precarious circumstances. Consequently, a potential techniques are used to identify and to assess for adapting and managing climate change to lessen the potential devastating impacts[1-3].

Global climate change affects the farming industry and water supplies. The acquired tremendous relevance given the significance of agricultural policy for the availability of food and the reality that over 92% of world water (global groundwater) is utilized by farming looked at how weather shifts affect farmers' need for water. In addition, the impacts of global warming on agricultural output were investigated and analyzed in [4, 5].

In agriculture, plans and decisions are utilized to accommodate climate change and global warming. In addition, Governments, farming industry executives, freshwater resources supervisors, and consumers adjust to novel circumstances in light of agriculture's central position in certain emerging nations and scarcity of water supplies, particularly in arid and semi-arid areas[6, 7]. Recently, adaptive techniques have been developed to assist in increasing awareness of dangers and decreasing exposure of global warming. Moreover, emerging technologies and expert systems for evaluation the management of agriculture water during the current complex nature issues [8–10].

The adjustment researches utilize from MCDM methodologies to choose and to assess recommended solutions with respect to several objectives[11, 12]. The adaptability solutions are useful and efficient for subsequent planning due to diverse aims of the participants and standards, and the necessity to include the views of experts in critical vital aspects e.g., water supply, farming, and ecology. The MCDM methodologies use an assessment tool to determine the objectives of long-term aims and to provide light on the relative merits of various adaption options[13, 14].

Regional management is the procedures for supervising an organization's business operations in a designated geographic area. In order to priorities sustainability in regional management, a new fuzzy multi-criteria assessment technique is developed, with foundation in a novel neutrosophic fuzzy method for capturing ambiguity in human judgements. To deal with such vague and unreliable data, the study illustrates the generalizations of fuzzy sets (FSs) and intuitionistic fuzzy sets (IFSs) to achieve appropriate solutions. However, many forms of fuzzy (MCDM) are classified to be inadequate for handling the ambiguity and incoherence of real-world data[15–17].

Hence, Smarandache proposed a new area of mathematics of neutrosophy focuses on "the source, the environment, and the extent of neutralities, in addition to relationships with various ideational spectra." In neutrosophy principal ideas are partially true, false, and indeterminate. The neutrosophic set (NS) is associated with philosophy alongside a very complex representation in practical contexts such as science and engineering. A single-valued neutrosophic set (SVNS) are illustrated with attributes as a means of addressing issue [18].

In selecting long-term partners in the medical field in Bosnia and Herzegovina, Stevi, et al. recently presented the MARCOS method. In the steel industry, this process is used to choose suppliers. Milling, crushing, and rotating are all ways in which it has been utilized in MCDM operations [19].

The remainder of the paper is structured as follows: Section 2 shows the proposed method that will be used to rank regional management alternatives with respect to groundwater resources. Section 3 introduces a numerical application with optimal ranking of alternatives to aid decision makers. Section 4 concludes the summary and the future work of the current study.

2. Neutrosophic MARCOS Method

The study ranks regional management alternatives with respect to groundwater resources. In addition, study adopts neutrosophic theory to handle unpredictable cases. The proposed decision-making approach integrates neutrosophic sets with the MARCOS method for achieving optimal solutions. The study presents a novel MARCOS method under neutrosophic sets to rank relational management alternatives. The study introduces the single valued neutrosophic sets to evaluate the criteria and alternatives [20, 21]. The steps of the neutrosophic MARCOS method are mentioned as follows and modeled in Figure 1:

Step 1: Identify study objective. Decompose problem hierarchy to represent the goal, criteria, and the possibility of alternatives.

Step 2: Build the decision matrix by aggregating decision maker's perspectives.

The formulation to build matrix between criteria and alternatives mentioned as follows:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix} \tag{1}$$

Step 3: Determine the ideal and anti-ideal solutions. The decision matrix is extended by inserting ideal and anti-ideal solutions into a decision matrix as follows:

$$A = \begin{matrix} \beta \\ \vdots \\ \gamma \end{matrix} \begin{bmatrix} a_{\beta 1} & \cdots & a_{\beta n} \\ \vdots & \ddots & \vdots \\ a_{\gamma 1} & \cdots & a_{\gamma n} \end{bmatrix} \tag{2}$$

$$\begin{pmatrix} \beta = \min a_{ij} \ , \gamma = \max a_{ij} \ , for\ benefit\ criteria \\ \beta = \max a_{ij} \ , \gamma = \min a_{ij} \ , for\ cost\ criteria \end{pmatrix} \tag{3}$$

Step 4: Compute the normalization extended decision matrix and defined as:

$$N_{ij} = \begin{bmatrix} \left(\frac{a_\gamma}{a_{ij}}\right) \ for\ cost\ criteria \\ \left(\frac{a_{ij}}{a_\gamma}\right) \ for\ benefit\ criteria \end{bmatrix} \tag{4}$$

Step 5: Compute the weighted normalized decision matrix presented as:

$$E_{ij} = (N_{ij} \cdot w_j) \tag{5}$$

Step 6: Compute the values of utility degree as follows:

$$U_i^- = \frac{D_i}{D_\beta} \tag{6}$$

$$U_i^+ = \frac{D_i}{D_\gamma} \tag{7}$$

$$D_i = \sum_{i=1}^{m} E_{ij} \tag{8}$$

Step 7: Compute the function of utility degree which defined as:

$$F(U_i) = \frac{U_i^+ + U_i^-}{1 + \frac{1 - FU_i^+}{FU_i^+} + \frac{1 - FU_i^-}{FU_i^-}} \tag{9}$$

$$FU_i^- = \frac{U_i^+}{U_i^+ + U_i^-} \tag{10}$$

$$FU_i^+ = \frac{U_i^-}{U_i^+ + U_i^-} \tag{11}$$

Step 8: Rank alternatives and choose the optimal decision alternative.

Figure 1. The neutrosophic MARCOS method.

3. Application

This section illustrates an application of single valued neutrosophic MARCOS method in real world problems. The study aims to rank and to recommend the best regional management in AWM. The study invited two experts to evaluate the criteria and alternatives. The experts' perspectives are gathered to detect the main criteria and organized as follow: acceptance, resource consumption, social, economy, ecological, feasibility, effectiveness, and flexibility with ten regions. The economy is the cost criteria, and all other criteria are benefit criteria.

Initial experts are evaluated the criteria and alternatives to build the decision matrix as shown in Table 1. Then compute the weights of criteria to give rank of importance criteria. The ecological criterion is the highest importance followed by feasibility and effectiveness. The flexibility criterion is the lowest importance criterion. Figure 2 shows the importance of all criteria.

Table 1. The initial decision matrix.

AWMAs	**AWMC$_1$**	**AWMC$_2$**	**AWMC$_3$**	**AWMC$_4$**	**AWMC$_5$**	**AWMC$_6$**	**AWMC$_7$**	**AWMC$_8$**
AWMA$_1$	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(1.0,0.1,0.1)
AWMA$_2$	(0.9,0.1,0.2)	(0.4,0.5,0.6)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.9,0.1,0.2)
AWMA$_3$	(1.0,0.1,0.1)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.7,0.3,0.4)	(0.8,0.2,0.3)
AWMA$_4$	(0.8,0.2,0.3)	(1.0,0.1,0.1)	(0.6,0.4,0.5)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(1.0,0.1,0.1)
AWMA$_5$	(1.0,0.1,0.1)	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(0.4,0.5,0.6)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(1.0,0.1,0.1)	(0.7,0.3,0.4)
AWMA$_6$	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.3,0.6,0.7)	(0.6,0.4,0.5)	(0.9,0.1,0.2)	(0.8,0.2,0.3)
AWMA$_7$	(0.9,0.1,0.2)	(1.0,0.1,0.1)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(1.0,0.1,0.1)	(0.6,0.4,0.5)
AWMA$_8$	(1.0,0.1,0.1)	(0.2,0.7,0.8)	(0.8,0.2,0.3)	(0.3,0.6,0.7)	(1.0,0.1,0.1)	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(1.0,0.1,0.1)
AWMA$_9$	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.2,0.7,0.8)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.7,0.3,0.4)
AWMA$_{10}$	(1.0,0.1,0.1)	(1.0,0.1,0.1)	(0.8,0.2,0.3)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(1.0,0.1,0.1)	(0.9,0.1,0.2)	(1.0,0.1,0.1)

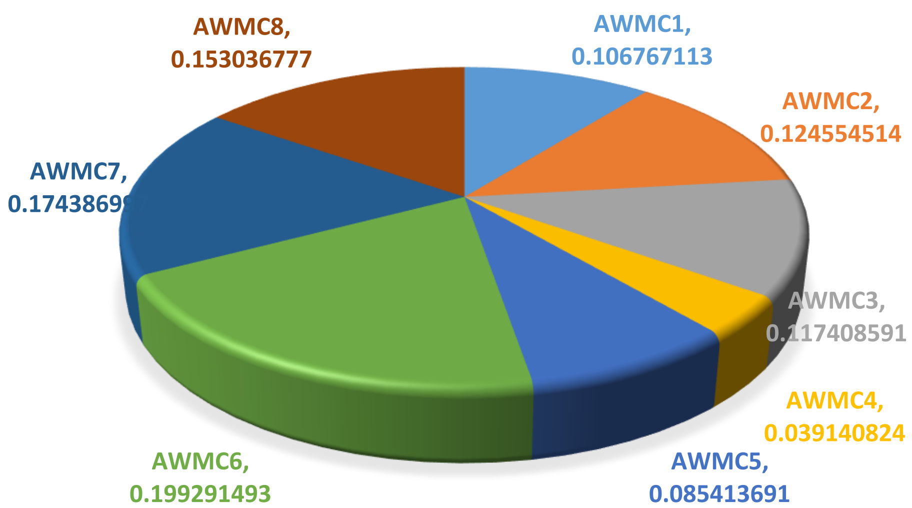

Figure 2. The importance of eight criteria.

Then extended the decision matrix by adding the ideal and anti-ideal solution. Then normalize the decision matrix by using Eq. (4) by using cost and benefit criteria. The normalization of extended decision matrix is shown in Table 2.

Table 2. The normalization of extended decision matrix.

AWMAs	**AWMC$_1$**	**AWMC$_2$**	**AWMC$_3$**	**AWMC$_4$**	**AWMC$_5$**	**AWMC$_6$**	**AWMC$_7$**	**AWMC$_8$**
AWMA$_1$	0.61534	0.589307	0.760823	0.535749	3.71472	0.61534	0.535717	0.571429
AWMA$_2$	0.576918	0.464267	0.586954	0.714347	4.000171	1	0.714347	0.92864
AWMA$_3$	0.673013	0.48216	0.760823	0.535749	1.928723	0.61534	0.48216	0.821461

AWMA₄	0.519211	1	0.45652	1	1.928723	0.76924	0.48216	0.571429
AWMA₅	0.673013	0.607168	1	0.464267	2.500054	0.884585	0.571429	0.714347
AWMA₆	0.519211	0.48216	0.869605	0.92864	1	0.653825	0.535749	0.48216
AWMA₇	1	0.571429	0.521756	1	2.142961	0.76924	1	0.607168
AWMA₈	0.673013	0.249973	0.64563	0.249989	2.285815	0.653825	0.48216	1
AWMA₉	0.519211	0.428603	0.304303	0.92864	1.928723	0.884585	0.589307	0.714347
AWMA₁₀	0.61534	0.571429	0.586954	0.571429	3.71472	0.61534	0.535749	1

Then multiply the weights of criteria by the normalized extended decision matrix by using Eq. (5) as shown in Table 3.

Table 3. The weighted normalization of extended decision matrix.

AWMAs	AWMC₁	AWMC₂	AWMC₃	AWMC₄	AWMC₅	AWMC₆	AWMC₇	AWMC₈
AWMA₁	0.065698	0.073401	0.089327	0.02097	0.317288	0.122632	0.093422	0.08745
AWMA₂	0.061596	0.057826	0.068913	0.02796	0.341669	0.199291	0.124573	0.142116
AWMA₃	0.071856	0.060055	0.089327	0.02097	0.164739	0.122632	0.084082	0.125714
AWMA₄	0.055435	0.124555	0.053599	0.039141	0.164739	0.153303	0.084082	0.08745
AWMA₅	0.071856	0.075626	0.117409	0.018172	0.213539	0.17629	0.09965	0.109321
AWMA₆	0.055435	0.060055	0.102099	0.036348	0.085414	0.130302	0.093428	0.073788
AWMA₇	0.106767	0.071174	0.061259	0.039141	0.183038	0.153303	0.174387	0.092919
AWMA₈	0.071856	0.031135	0.075802	0.009785	0.19524	0.130302	0.084082	0.153037
AWMA₉	0.055435	0.053384	0.035728	0.036348	0.164739	0.17629	0.102767	0.109321
AWMA₁₀	0.065698	0.071174	0.068913	0.022366	0.317288	0.122632	0.093428	0.153037

Then compute the utility of degrees using Eqs. (6), (7), and (8). Then compute the function of utility degree using Eqs. (9), (10), and (11). Then order the alternatives as shown in Figure 3. The alternative ten is the highest score followed by alternative eight then alternative two. The lowest score of alternatives is one.

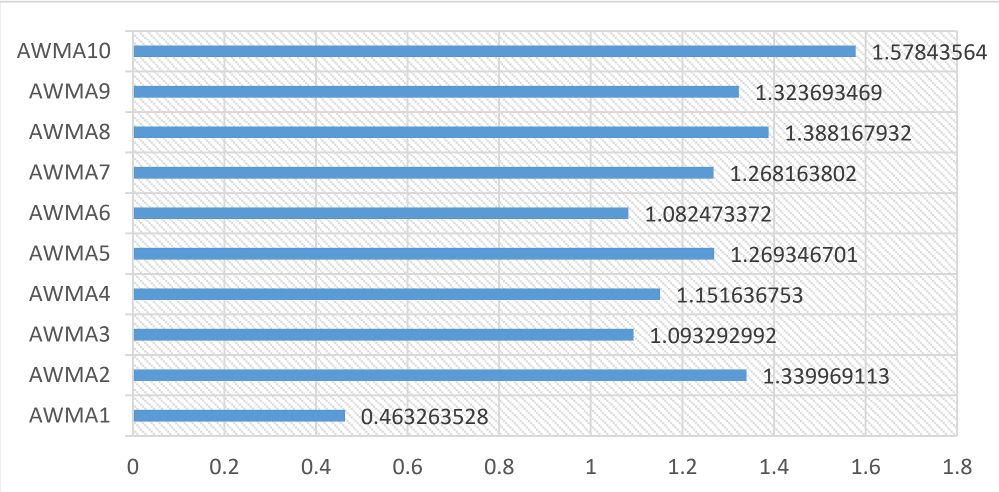

Figure 3. The order of ten options in AWM.

4. Conclusions

This research creates and employs a theoretical structure of planning and MCDM for efficient and environmentally friendly use of water resources in agriculture. In addition, a multi-factor analytical approach was created to predict water for agriculture purposes. Regional management alternatives for handling agriculture water demand as well as supply were defined based on the findings of an investigation of water usage in agriculture and the identification of both internal and outside factors affecting the administration of water resources for farming.

The usage of a procedure takes into consideration ambiguity and uncertainty during decision-making. Consequently, eight water supply standards were established: social, economic, ecological, and water use administration. The proposed approach was applied to ten alternatives with respect to the impact of criterion strengths in MCDM. The given approach integrated the neutrosophic sets with the MARCOS method to aid decision makers to achieve the optimal solutions. Hence, the results show the alternative 10 as the best and alternative 1 is the worst.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

References

1. A. Radmehr, O. Bozorg-Haddad, and H. A. Loáiciga, “Developing strategies for agricultural water management of large irrigation and drainage networks with Fuzzy MCDM,” *Water Resour. Manag.*, vol. 36, no. 13, pp. 4885–4912, 2022.
2. M. E. Banihabib and M. H. Shabestari, “Fuzzy hybrid MCDM model for ranking the agricultural water demand management strategies in arid areas,” *Water Resour. Manag.*, vol. 31, pp. 495–513, 2017.
3. R. Zamani, A. M. A. Ali, and A. Roozbahani, “Evaluation of adaptation scenarios for climate change impacts on agricultural water allocation using fuzzy MCDM methods,” *Water Resour. Manag.*, vol. 34, pp. 1093–1110, 2020.
4. S. Burak, F. Samanlioglu, and D. Ülker, “Evaluation of irrigation methods in Söke Plain with HF-AHP-PROMETHEE II hybrid MCDM method,” *Agric. Water Manag.*, vol. 271, p. 107810, 2022.
5. P. Golfam, P.-S. Ashofteh, T. Rajaee, and X. Chu, “Prioritization of water allocation for adaptation to climate change using multi-criteria decision making (MCDM),” *Water Resour. Manag.*, vol. 33, pp. 3401–3416, 2019.
6. J. Berbel, D. Viaggi, and B. Manos, “Estimating demand for irrigation water in European Mediterranean countries through MCDM models,” *Water Policy*, vol. 11, no. 3, pp. 348–361, 2009.
7. E. Xevi and S. Khan, “A multi-objective optimisation approach to water management,” *J. Environ. Manage.*, vol. 77, no. 4, pp. 269–277, 2005.
8. M. Karamouz, B. Zahraie, and R. Kerachian, “Development of a master plan for water pollution control using MCDM techniques: a case study,” *Water Int.*, vol. 28, no. 4, pp. 478–490, 2003.
9. J. A. Gómez-Limón, J. Berbel, and M. Arriaza, “MCDM farm system analysis for public management of irrigated agriculture,” *Handb. Oper. Res. Nat. Resour.*, pp. 93–114, 2007.
10. S. G. Kharanagh, M. E. Banihabib, and S. Javadi, “An MCDM-based social network analysis of water governance to determine actors’ power in water-food-energy nexus,” *J. Hydrol.*, vol. 581, p. 124382, 2020.

11. N. Akhtar *et al.*, "Modification of the water quality index (WQI) process for simple calculation using the multi-criteria decision-making (MCDM) method: a review," *Water*, vol. 13, no. 7, p. 905, 2021.
12. M. Orojloo, S. M. H. Shahdany, and A. Roozbahani, "Developing an integrated risk management framework for agricultural water conveyance and distribution systems within fuzzy decision making approaches," *Sci. Total Environ.*, vol. 627, pp. 1363–1376, 2018.
13. A. Roozbahani, E. Ebrahimi, and M. E. Banihabib, "A framework for ground water management based on bayesian network and MCDM techniques," *Water Resour. Manag.*, vol. 32, pp. 4985–5005, 2018.
14. M. Ebad Ardestani, E. Sharifi Teshnizi, P. Babakhani, M. Mahdad, and M. Golian, "An optimal management approach for agricultural water supply in accordance with sustainable development criteria using MCDM (TOPSIS)(Case study of Poldasht catchment in West Azerbaijan Province-Iran)," *J. Appl. Water Eng. Res.*, vol. 8, no. 2, pp. 88–107, 2020.
15. P. Golfam, P.-S. Ashofteh, and H. A. Loáiciga, "Evaluation of the VIKOR and FOWA multi-criteria decision making methods for climate-change adaptation of agricultural water supply," *Water Resour. Manag.*, vol. 33, pp. 2867–2884, 2019.
16. M. M. Zewdie and C. Tesfa, "GIS-based MCDM modeling for suitable dam site identification at Yeda watershed, Ethiopia," *Arab. J. Geosci.*, vol. 16, no. 6, p. 369, 2023.
17. T. Balezentis, X. Chen, A. Galnaityte, and V. Namiotko, "Optimizing crop mix with respect to economic and environmental constraints: An integrated MCDM approach," *Sci. Total Environ.*, vol. 705, p. 135896, 2020.
18. R. S. U. Haq *et al.*, "Sustainable material selection with crisp and ambiguous data using single-valued neutrosophic-MEREC-MARCOS framework," *Appl. Soft Comput.*, vol. 128, p. 109546, 2022.
19. D. Pamucar, F. Ecer, and M. Deveci, "Assessment of alternative fuel vehicles for sustainable road transportation of United States using integrated fuzzy FUCOM and neutrosophic fuzzy MARCOS methodology," *Sci. Total Environ.*, vol. 788, p. 147763, 2021.
20. Y. Rong, W. Niu, H. Garg, Y. Liu, and L. Yu, "A hybrid group decision approach based on MARCOS and regret theory for pharmaceutical enterprises assessment under a single-valued neutrosophic scenario," *Systems*, vol. 10, no. 4, p. 106, 2022.
21. P. Majumder, "An Integrated Trapezoidal Fuzzy FUCOM with Single-valued Neutrosophic Fuzzy MARCOS and GMDH Method to Determine the Alternatives Weight and its Applications in Efficiency Analysis of Water Treatment Plant," *Expert Syst. Appl.*, p. 120087, 2023.

Received: May 26, 2022. Accepted: Jan 22, 2023