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Fuzzy logical model for assessing soil salinity

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Fuzzy logical model for assessing soil salinity

D T Muhamediyeva*

National Research University "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers"39 Kara Niyazov Street, Tashkent, Republic of Uzbekistan

* E-mail: dilnoz134@rambler.ru

Abstract. The relevance of the development of theoretical and methodological tools for constructing a fuzzy logical model for assessing soil salinity is due to the automation of the formation of a base of fuzzy rules from a given set of certain conditions, checking the correctness of the constructed rules with criteria for the adequacy of fuzzy models and creating algorithms and programs using standard algorithms and software modules for solving fuzzy logic problems. conclusion and decision-making based on the constructed models for assessing soil salinity.

1. Introduction

Currently, the total land area of the Republic of Uzbekistan is about 45 million hectares, irrigated land - 4 million 331 thousand hectares, which is only 9.7% of the total land area. The assessment of soil salinity to increase the productivity of biomass is topical. Nutrients in the soil that are obtained from crops must be replenished [1].

If the concentration of salts in soils exceeds the limits of toxicity - 3-5 g/l, such soils are classified as saline soils.

When evaluating soils by suitability, soil classification by salinity is used, which takes into account the salt tolerance of plants [2].

Problems faced by specialists in solving classification problems [3-7]:

lack of relevant information in real time;

lack of databases of documented information and, as a result, the absence of an automated decision support system;

lack of knowledge bases and rule bases for solving classification problems;

lack of integrated software systems.

The most common methods for solving classification problems are: Mamdani, Tsukamoto, Larsen, Takagi-Sugeno. Below is a comparative analysis of fuzzy models [8-17]:

In our study, the Mamdani model [9] was used.

2. Methods and models

The problem of soil salinity assessment is considered, which is described by the Mamdani fuzzy logical model [5]:

$$\bigcup_{p=1}^{k_j}\left(\bigcap_{i=1}^{n} x_i = a_{i,jp} - \text{with weight } w_{jp}\right) \to y = d_j$$

Here: $a_{i,jp}$ term in conjunction-string jp ($jp=\overline{1,k_j}$).

An algorithm for the problem of estimating soil salinity has been developed.
1. Fuzzification. Membership function $a_{i,jp}$ choose as follows:

$$\tilde{\mu}^l(x_i^j) = \left[1 + \left(\frac{x_i^j - c_l^j}{\sigma_l^j}\right)^2\right]^{-1}.$$

2. Fuzzy output:

$$\mu_{d_j}\left(x_1, x_2, ..., x_n\right) = \bigcup_{p=1}^{k_j}\left\{w_{jp}\left[\bigcap_{i=1}^{n}\mu_{a_i^{jp}}\left(x_i\right)\right]\right\}.$$

3. Composition:

$$\mu_{d_j}\left(x_1, x_2, ..., x_n\right) = \max_{p=\overline{1,k_j}}\left\{w_{jp}\min_{i=\overline{1,n}}\left[\mu_{a_i^{jp}}\left(x_i\right)\right]\right\}, j=\overline{1,m}.$$

4. Defuzzification by the centroid method.
A fuzzy logical model Mamdani for assessing soil salinity has been constructed.

If $\left(x_1 = \frac{\sum_{j=1}^{q}\mu(a_{11}^j)a_{11}^j}{\sum_{j=1}^{q}\mu(a_{11}^j)} \wedge x_2 = \frac{\sum_{j=1}^{q}\mu(a_{12}^j)a_{12}^j}{\sum_{j=1}^{q}\mu(a_{12}^j)} \wedge ... \wedge x_8 = \frac{\sum_{j=1}^{q}\mu(a_{18}^j)a_{18}^j}{\sum_{j=1}^{q}\mu(a_{18}^j)}\right)$

then y = non-saline soils.

If $\left(x_1 = \frac{\sum_{j=1}^{q}\mu(a_{21}^j)a_{21}^j}{\sum_{j=1}^{q}\mu(a_{21}^j)} \wedge x_2 = \frac{\sum_{j=1}^{q}\mu(a_{22}^j)a_{22}^j}{\sum_{j=1}^{q}\mu(a_{22}^j)} \wedge ... \wedge x_8 = \frac{\sum_{j=1}^{q}\mu(a_{28}^j)a_{28}^j}{\sum_{j=1}^{q}\mu(a_{28}^j)}\right)$

then y = The degree of soil salinity is weak.

If $\left(x_1 = \frac{\sum_{j=1}^{q}\mu(a_{31}^j)a_{31}^j}{\sum_{j=1}^{q}\mu(a_{31}^j)} \wedge x_2 = \frac{\sum_{j=1}^{q}\mu(a_{32}^j)a_{32}^j}{\sum_{j=1}^{q}\mu(a_{32}^j)} \wedge ... \wedge x_8 = \frac{\sum_{j=1}^{q}\mu(a_{38}^j)a_{38}^j}{\sum_{j=1}^{q}\mu(a_{38}^j)}\right)$

then y = degree of salinity of the soil is average.

If $\left(x_1 = \frac{\sum_{j=1}^{q}\mu(a_{41}^j)a_{41}^j}{\sum_{j=1}^{q}\mu(a_{41}^j)} \wedge x_2 = \frac{\sum_{j=1}^{q}\mu(a_{42}^j)a_{42}^j}{\sum_{j=1}^{q}\mu(a_{42}^j)} \wedge ... \wedge x_8 = \frac{\sum_{j=1}^{q}\mu(a_{48}^j)a_{48}^j}{\sum_{j=1}^{q}\mu(a_{48}^j)}\right)$

then y = The degree of salinity of the soil is strong.

$$\text{If}\left(x_1 = \frac{\sum_{j=1}^{q}\mu(a_{51}^{j})a_{51}^{j}}{\sum_{j=1}^{q}\mu(a_{51}^{j})} \wedge x_2 = \frac{\sum_{j=1}^{q}\mu(a_{52}^{j})a_{52}^{j}}{\sum_{j=1}^{q}\mu(a_{52}^{j})} \wedge \ldots \wedge x_8 = \frac{\sum_{j=1}^{q}\mu(a_{58}^{j})a_{58}^{j}}{\sum_{j=1}^{q}\mu(a_{58}^{j})} \right)$$

then y = The degree of soil salinity is very strong.

Here:

x_1 - acidity index of neutral salinity;

x_2 - total amount of salts at chloride, sulfate-chloride salinization; soils according to the ratio of ions, mmol (eq)/100 g of soil;

x_3 - total amount of salts during chloride-sulphate salinization of soils according to the ratio of ions, mmol (eq) / 100 g of soil;

x_4 - total amount of salts during sulfate salinization of soils according to the ratio of ions, mmol (eq) / 100 g of soil;

x_5 - acidity index of alkaline salinity;

x_6 - total amount of salts during soda and soda-chloride salinization of soils according to the ratio of ions, mmol (eq) / 100 g of soil;

x_7 - total amount of salts during sulphate-non-soda and soda-sulphate salinization of soils according to the ratio of ions, mmol (eq) / 100 g of soil;

x_8 - total amount of salts during sulphate-chloride-carbonate salinization of soils according to the ratio of ions, mmol (eq) / 100 g of soil.

In classification problems, task parameters depend on many factors that are difficult to take into account in the model. The introduction of these dependencies into the model significantly complicates it and increases the dimension of the problem, and "refinement of the model in this way in practice will come to naught due to the impossibility of measuring or measuring with sufficient accuracy the values of the factors introduced into the model" . That is, for model parameters, it would be more natural to specify an interval of possible values or a membership function.

Approximation of membership functions and fuzzy relations is based on the choice among the membership functions that are consistent with a given ratio, the one that best approximates the presented membership function.

Most of the work on the problem of constructing membership functions is related to the methods of processing expert data and the results of a survey of specialists. The method makes it possible to include some subjective restrictions into the system restrictions, which may be caused by the fact that a person has a number of informal information about the system in natural language.

For example, the statement "The acidity index of neutral salinity must be less than 0.8" can be represented as follows:

$$\mu(a_{11}^{j}) = \begin{cases} 1, & a_{11} \le 8.5, \\ \left([1+(a_{11}-8.5)]^2\right)^{-1}, & a_{11} > 8.5. \end{cases}$$

"The total amount of salts during chloride, sulfate-chloride salinization of soils in terms of the ratio of ions, mmol (eq) / 100 g of soil should be less than 0.1" can be represented as follows:

$$\mu(a_{12}^{j})=\begin{cases}1, & a_{12}\le 0.1,\\ \left[1+\dfrac{(a_{12}-0.1)^2}{0.001}\right]^{-1}, & a_{12}>0.1.\end{cases}$$

"The total amount of salts during chloride-sulfate salinization of soils in terms of the ratio of ions, mmol (eq) / 100 g of soil should be less than 0.2" can be represented as follows:

$$\mu(a_{13}^{j})=\begin{cases}1, & a_{13}\le 0.2,\\ \left[1+\dfrac{(a_{12}-0.2)^2}{0.004}\right]^{-1}, & a_{13}>0.2.\end{cases}$$

The statement "The acidity index of the alkaline salinity must be greater than 0.8" can be expressed as follows:

$$\mu(a_{25}^{j})=\begin{cases}\left[1+\dfrac{(a_{25}-8.5)^{-1}}{0.9}\right]^{-1}, & a_{25}\ge 8.5,\\ 0, & a_{25}<8.5.\end{cases}$$

The statement "The total amount of salts in the case of soda and soda-chloride salinization of soils in terms of the ratio of ions, mmol (eq) / 100 g of soil should be close to 0.15" can be represented as follows:

$$\mu(a_{26}^{j})=\left[1+\frac{(a_{26}-0.15)^2}{0.002}\right]^{-1}.$$

The statement "The total amount of salts during sulphate-non-soda and soda-sulphate salinization of soils in terms of the ratio of ions, mmol (eq) / 100 g of soil should be close to 0.2" can be represented as follows:

$$\mu(a_{27}^{j})=\left[1+\frac{(a_{27}-0.2)^2}{0.004}\right]^{-1}.$$

Using the membership function, you can adequately reflect the opinion of one or more experts. This is due to the inability of a person to formulate his quantitative impression as a single number.

3. Result

Results of classification according to the Mamdani fuzzy logical model are obtained and a comparative analysis is carried out.

Table 1. Accuracy of the results calculated using the Mamdani neuro-fuzzy model (%).

№	Value of σ	Number of terms			
		3	5	7	9
1	0.10	93.75	93.75	93.75	97.92
2	0.20	93.75	93.75	93.75	97.92
3	0.30	91.67	93.75	93.75	97.92
4	0.40	89.58	93.75	93.75	97.92
5	0.50	87.50	93.75	93.75	97.92

6	0.60	87.50	93.75	93.75	97.92
7	0.70	87.50	93.75	93.75	97.92
8	0.80	87.50	93.75	93.75	97.92
9	0.90	87.50	93.75	91.67	97.92
10	1.00	87.50	93.75	91.67	97.92
		93.75	93.75	93.75	97.92

According to the predicted results, the area of saline lands in 2022 will be 1884 thousand hectares, in 2025 there will be 1810 thousand hectares.

4. Conclusion

A model for assessing soil salinity using the Mamdani fuzzy logic apparatus has been developed, and the possibility of obtaining quantitative estimates in a fuzzy model has been shown. The algorithm works on the "black box" principle. The input receives quantitative and qualitative values in a linguistic form, the output is in the form of a term as the degree of soil salinity is weak, the degree of soil salinity is medium. When building a model, the apparatus of fuzzy logic and the theory of fuzzy sets are used. This points to the advantage of using fuzzy systems. It is possible to manipulate linguistic data using fuzzy inference systems.

References

[1] Kharkiv 2012 *Chemical soil reclamation* (the concept of innovative development) p 130
[2] Turdaliev Zh M, Mansurov Sh S, Akhmedov A U and Abdurakhmonov N Yu 2019 Salinity of soils and groundwaters of the Ferghana Valley *Scientific Review. Biological Sciences* **2** 10–15
[3] Chen G et al 2006 A new approach to classification based on association rule mining *Decis. Support Syst.* **42** 674–689
[4] Egamberdiev N, Mukhamedieva D and Khasanov U 2020 Presentation of preferences in multi-criterional tasks of decision-making *IOP Conf. Series:Journal of Physics* (Conference Series **1441** 012137 DOI: https://doi.org/10.1088/1742-6596/1441/1/012137)
[5] Kalandarov P I, Mukimov Z M and Nigmatov A M 2022 Automatic Devices for Continuous Moisture Analysis of Industrial Automation Systems *Lecture Notes in Mechanical Engineering* pp 810–817 https://doi.org/10.1007/978-3-030-85230-6_96
[6] Kalandarov P I and Abdullayev K K 2022 Features of the technology of anaerobic processing of biotails using humidity control devices *IOP Conference Series: Earth and Environmental Science* **1043(1)** 012011
[7] Kalandarov P I and Abdullaeva D A 2022 Innovative approach to the development of hydroponic green feeds *IOP Conference Series: Earth and Environmental Science* **1043(1)** 012012
[8] Kalandarov P I and Mukimov Z M 2022 Humidity Control During Hydrothermal Treatment of Grain and Their Processed Products *Lecture Notes in Mechanical Engineering* pp 966–981 https://doi.org/10.1007/978-3-031-14125-6_94
[9] Han Y, Lam W and Ling C X 2007 Customized classification learning based on query projections *Information Sciences* **177** 3557–3573
[10] Mamdani E H and Efstathion H J 1985 Higher -order logics for handling uncertainty in expert systems *Int. J. Man -Mach. Stud.* **3** 243–259
[11] Muhamediyeva D T 2019 Aproaches to the Construction of Fuzzy Models of Intellectual Analysis of the State of the Low-Formalized Processes *2019 International Conference on Information Science and Communications Technologies (ICISCT)* (Tashkent, Uzbekistan) pp 1-5

[12] Muhamediyeva D T 2022 Building and training a fuzzy neural model of data mining tasks *IOP Conf. Series: Journal of Physics: Conference Series* **2182** 012024 DOI https://doi.org/10.1088/1742-6596/2182/1/012024)
[13] Zagidullin B I, Nagaev I A, Zagidullin N Sh and Zagidullin Sh Z 2012 A neural network model for the diagnosis of myocardial infarction *Russian Journal of Cardiology* **6** 51–54
[14] Zaychenko Yu 2006 The Fuzzy Group Method of Data Handling and Its Application for Economical Processes forecasting *Scientific Inquiry* **1 (7)** 83–98
[15] Rotshtein A P 2009 Fuzzy multicriteria choice of alternatives: worst case method *Theory and control systems* (Izv. RAN.) **3** 51–55
[16] Rutkovskaya D, Pilinsky M and Rutkovsky L 2004 Neural networks, genetic algorithms and fuzzy systems (Translated from Polish. I.D. Rudinsky. -M.: Hotline-Telecom) p 452
[17] Siddikov I X, Kalandarav P I and Yadgarova D B 2021 Engineering Calculation And Algorithm Of Adaptation Of Parameters Of A Neuro-Fuzzy Controller *The American Journal of Applied sciences* **3 (09)** 41–49