Using the Mamdani algorithm for Location evaluation of linear objects on agricultural land

V V Vershinin¹, L YU Piterskaya², M V Sidorenko²*¹

¹State University of Land Use Planning, Moscow, 105064, Russia,
²Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, 350044, Russia

*E-mail: sidorenko1mv@mail.ru

Abstract. The paper considers an algorithm of using the author's methodology for location evaluation of agricultural objects on agricultural land, based on an expert-qualimetric approach to the analysis of factors in the use of agricultural land and rural development. Location evaluation of linear objects on land plots used in agricultural production leads to violations of the integrity of land use, negatively affects the quality of soils, makes it difficult to carry out technological work on their processing, entails inevitable economic losses of landowners and land users. At the same time, linear facilities (roads, oil and gas pipelines, energy networks, etc.) play an important positive role in the development of the country and its rural areas and the agricultural sector as a whole. In this regard, the problem of evaluation the location of a linear object is actualized, based on the balance of interests. The authors believe that the first expert approach (pre-project) proposed in this publication.

1. Introduction

The modern development of industry and the constant growth of cities require the construction of new linear facilities, as well as the reconstruction of existing ones. The construction of linear structures leads to gradual decrease in land quality, withdrawal of valuable agricultural land from circulation, violations of land use structure, and loss of economic benefits for landowners [6,8,14].

Linear facilities are characterized by a large extent and can be located on different land categories, they have the most tangible impact (both positive and negative) on agricultural land and agricultural production. The level of their impact on land use depends on the type of linear facility and the conditions of its placement and operation [1,3]. For example, roads and railways can have irreversible negative consequences when mistakes are made in choosing their location, leading to the retirement of large tracts of agricultural land. Power lines have less impact on agricultural production. An underground pipeline leads to less inconveniences than an above-ground pipeline. Moreover, the underground pipeline when lying from 80 cm in depth allows the land use without consequences for agricultural production. The exception may be areas occupied by perennial plantings.

It should be noted that when choosing the optimal placement option a linear object, it is necessary to consider the specialization of agricultural enterprises, which largely determines the level of their losses [9].

In this way, the level of negative consequences during the construction of linear facilities should be assessed if a multidimensional analysis is applied: analysis of the characteristics of the projected linear facility; land use structure; efficiency and agricultural production itself. At the same time, the lack of
proper justification for the allocation of agricultural land for linear facilities leads to the adoption of irrational design decisions [12].

Modern methods of justifying the choice of the location of a linear object, on the basis of which the final conclusion on their placement is made, have a number of significant drawbacks, namely: the main economic calculations are reduced to estimates of the construction costs and the cost of operating the building, and the possible (obvious) damage is estimated only in relation to the natural environment. That is the negative consequences associated with the placement of linear objects for agricultural land users are not taken into account [2, 4].

This approach to decision-making is also facilitated by the current legislation, which does not provide for long-term compensation for negative consequences (losses, damages and lost profits), in case of violation of the land-use territory. In the case of proof of losses from such violations, only one-time payments are made (extremely rarely), which are not acceptable for agricultural production, since the resulting violations are usually irreversible.

The author's methodological approach to assessing the feasibility and effectiveness of linear facilities placement on agricultural land is based on a multidimensional assessment and is based on the analysis of four groups of indicators (technical, economic, social, and environmental). Each group of indicators includes positive and negative results of linear facility placement.

The result of the presented approach implementation is the determination of the integral indicator using the Mamdani fuzzy inference system.

The proposed method is universal, since the possible input of variables provides for an assessment of the effectiveness of linear facilities placement of all types based on the results of its input and operation (positive and negative).

Previously, this approach was not used in the field of planning the linear facilities placement and their operation. Nevertheless, the general algorithm and rules for applying the fuzzy inference system are acceptable when analyzing linear facilities placement.

2. Materials and Methods

The condition for effective and rational land use is the possibility of prompt decision-making when choosing the location of linear facility [9]. During the development of the methodological approach, many projects for the placement and construction of linear facilities were analyzed. Each linear facility has a protected zone, the width of which depends on the type of linear facility and its elements. In the protected zone, there is several restrictions on the land use [13].

An example of rational and irrational placement of linear facility (power line) is shown in Figure 1.

Currently, design organizations, in consultation with the local administration bodies, decide to choose the option of passing a linear structure. Often, the linear facility placement is not justified. Figure 1 confirms the fact that in one case, the situation was considered, namely, the configuration of the arable land plot and the direction of its processing, and in the second case, they sought to reduce construction costs.

In each individual case, it is necessary to evaluate the results of linear facility construction by economic, social, technical, and environmental indicators.
Expert-qualimetric evaluation of linear facility placement efficiency enables a comparative assessment of not one but many design options that will allow to choose the most optimal variant, which will consider interests of land owners on which a linear facility is placed, impact on land use and linear facility operation results [10].

A distinctive feature of the proposed approach, which includes the calculation of an integral indicator for evaluating the feasibility of linear facilities placement, is the involvement of individual discipline experts. For example, one expert is not able to reliably assess the degree of linear facility influence on economic and environmental indicators.

The expert-qualimetric approach for determining the assessment of the placement of a linear facility is based on the consideration of the result, based on a set of indicators that reflect a positive or negative effect.

Evaluation result is considered as a set of separate groups of indicators that reflect the individual consequences of linear facilities placement. Experts evaluate groups of indicators for linear facility in quantitative form (in points), while determining the criteria for its acceptable value of the integral indicator for decision making.

To evaluate the effectiveness of linear facility placement, we propose to determine the integral indicator for evaluating the feasibility of linear facility placement and the criteria for its acceptable value for positive decision making.

Depending on the linear facility, its purpose, location, and other characteristics, the values of each indicator will change. That is, each group for different types of linear facilities will have a certain weight. It is worth noting that for each group of indicators, both the positive effect and the negative consequences can be evaluated.

For quantitative evaluation of the integral indicator of linear facility placement feasibility, we used the fuzzy modeling methodology (Mamdani fuzzy inference system). Unlike traditional mathematics, fuzzy logic offers a completely different level of thinking, thanks to which the creative modeling process takes place at a higher level of abstraction, in which only a minimal set of regularities is postulated.

To achieve this goal, four linguistic variables <βi, Ti, X, Gi, Mi>, i=1,2,3,4 were considered, describing each of the factors considered above, taking into account its degree of influence on the result. Here βi – name of linguistic variable, Ti – set of variable values (base term-set), each of which represents the name of a separate fuzzy variable, X – domain of fuzzy variables, Gi – syntactical procedure, describing the process of new variables formation, Mi – semantic procedure that matches each value of variable - a fuzzy set.

In this paper, the base term-set for each variable was defined as consisting of three values-levels:

- HI — high influence degree (high influence)
MI — medium influence degree (middle influence)
LI — low influence degree (low influence).

Then, for example, the term set for a group of economic factors will have the form: T1= {"High impact of economic indicators on the result", "Medium impact of economic indicators on the result", "Low impact of economic indicators on the result"}.

The next step of the fuzzy inference procedure is the stage of fuzzification of the original term sets, that is, setting each fuzzy variable of the base term set considering the membership function. In this paper, preference was given to triangular functions that ensure the simplicity of their assignment from one side of the implementation, the fuzzy inference system on the other.

$$\mu(x, a, b, c) = \begin{cases} 0, & \text{если } x \leq a; \\ \frac{x - a}{c - a}, & \text{если } a < x \leq c; \\ \frac{b - x}{b - c}, & \text{если } c < x < b; \end{cases}$$

**Figure 2.** Setting the triangular function of variable's membership

### 3. Results and Discussion

To define triangular functions, as well as to demonstrate the fuzzy inference procedure, the MATLAB 2014a application software package containing the membership function editor included in the "Fuzzy" module was used.

Empirical knowledge about the problem area under consideration (quantitative assessment of the integral indicator) can be presented in the form of a complete and consistent system of rules (Table 1). Thus, the base of fuzzy production rules of the fuzzy inference system is a system of fuzzy production rules that reflects the knowledge of experts about the methods of managing a facility in different situations, the nature of its functioning in different conditions, etc., i.e., it contains formalized human knowledge.

| Groups of factors (incl degree of influence) | Integral indicator | Decision making   |
|---------------------------------------------|---------------------|-------------------|
| high                                       | low                 |                  |
| Econ., Soc. Tech.                          | Ecol.               | High             | Advisable to place |
| Econ., Soc. Ecol.                          | Tech.               | High             | Advisable to place |
| Econ., Soc. Tech.                          | Ecol.               | High             | Advisable to place |
| Econ. Tech.                                | Soc. Ecol.          | Medium           | Advisable to place |
| Tech. Econ.                                | Ecol. Soc.          | Medium           | Advisable to place |
| Ecol. Tech.                                | Ecol. Econ., Soc.   | Medium           | Advisable to place |
| Ecol. Tech.                                | Econ.               | Low              | Not advisable to place |
| Ecol., Tech.                               | Econ., Soc. Tech.   | Low              | Not advisable to place |

**Table 1.** Expert system of fuzzy inference rules
Based on them, it is easy to receive the value of the output variable for specific numeric values of the input variables. To do this, the degree of truth of each of the sub-conclusions is determined for each of the rules of the fuzzy inference system, which leads to one fuzzy set that will be assigned to each output variable for each rule. The fuzzy subsets assigned to each output variable are combined to form one fuzzy subset for each variable. Further, based on the rule for finding the figure center of gravity, using MATLAB, the output value of the desired variable "Integral indicator of the feasibility of placing a linear object" is determined.

Note that the original factor space is four-dimensional, which means that it is possible to graphically implement the dependence only if any two (out of four) variables are fixed in the range from 0 to 5. At the same time, if the average value of the indicator tends to 5, then this indicates that positive results prevail over negative consequences.

4. Conclusion
The data provided indicate that the presented methodology (methodological approach) allows you to quickly analyze the placement of a linear object on the territory of agricultural land-use. A feature that determines the ease of use of the proposed evaluation algorithms is that the expert does not need to know the calculated performance indicators, it is enough for him to evaluate in points the effect of placing a linear object for each group of indicators.

In fact, this scale is not exempt from criticism and can be supplemented or reduced depending on the conditions under consideration, as well as the type of linear facility. To do this, there are no restrictions, it is enough to change the scope of values of each variable and the scope of membership function definition.

We believe that the proposed assessment is most effectively carried out at the stage of approval of project proposals.

Acknowledgements
The article is published based on scientific results obtained with the financial support of the RFBR grant No. 19-44-230008 and the administration of the Krasnodar Krai.

References
[1] Antropov D V 2012 Features of land use in zones with special conditions of territory use Property relations in the Russian Federation 11 pp 6-10
[2] Barsukova G N, Yurchenko K A 2020 Regional features of the land resources of the Krasnodar Krai, Land management, cadastre and land monitoring pp 29-33
[3] Volkov S N, Lipski S A 2017 On measures to ensure the rational land use in agricultural production and reproduction of their fertility International Agricultural Journal 6 pp 10-13
[4] Komlatsky G V 2008 Improvement of economic mechanism for regulating land relations of agricultural enterprises in the region: monograph Maykop: ASU pp159
[5] Podkolzin O A, Sidorenko M V 2017 Improving land relations in linear facilities placement Land management, cadastre and land monitoring 2 pp 30-34
[6] Demyanova A D, Schastlivetskaya E A, Lipski S A 2019 Information support of management of the land resources of the Russian Federation IOP Conference series: earth and environmental science The proceedings 2019th International Symposium on Earth Sciences: History, Contemporary Issues and Prospects 012056
[7] Goloshchapova L V, Smolentsev V M, Korelskiy D S, Rudenko M N, Sergodeeva E A 2017 Theoretical and methodological basis of organization of the internal control system of the industrial enterprise International Journal of Applied Business and Economic Research 15 (12)
[8] Lidin K L, Meerovich M G, Bulgakova E A, Vershinin V V, Papaskiri T V 2018 Applying the theory of informational flows in urbanism for a practical experiment in architecture and land use Espacios 39 (1) pp 12

[9] Melnik M S 2019 Monitoring and certification of agricultural land by creating a bank of information resources for the rational use of steppe landscapes of the Western Ciscaucasia IOP Conference Series: Earth and Environmental Science 315 pp 20-28

[10] Mursayapov R R, Asylbaev I G, Kurmasheva N G, Lukmanov R A and Miftakhov I R 2019 Agroecological assessment of soils in the system of agricultural land use Bulgar J. of agricult. Sci. 25(52) pp 187-90

[11] Reznichenko S M, Shishkin V O, Shichiyakh R A, Smolentsev V M 2016 Theoretical and methodological foundations of the management by objectives for the regional socio-economic systems development International Review of Management and Marketing 6 (6) pp 90-94

[12] Volkov S N, Lipski S A 2017 About the measures to ensure rational use of lands in agricultural production and reproduction of their fertility International agricultural journal 6 pp 10-13

[13] Voronkova O, Vorozheykina T, Borisov V, Pilyugina A, Akhkiiamova G, Smolentsev V 2019 Ecological and economic preconditions for the use of fallow land in the development strategy of green economy Journal of Environmental Management and Tourism 10 5 (37) pp 1011-1019

[14] Vershinin V V, Fedorinov A V and Dontsov A V. 2019 The use of co variance matrices in laboratory processing of geo-environmental data of field survey for development projects of land use planning IOP Conference Series: Earth and Environmental Science 012073 pp 350