MULTI ATTRIBUTE ASSESSMENT APPROACH IN VEGETABLE PRODUCTION

Grujica Vico¹, Aleksandra Govedarica-Lučić², Zoran Rajić³, Radomir Bodiroga⁴, Ivan Mičić⁵, Silvija Zec Sambol⁶, Marija Mičić⁷

Summary

Two types of economic effectiveness and two types of economic efficiency, as well as three types of indicators as nutritional quality criteria were used in this paper for ranking certain winter lettuce growing technologies. Four certain types of growing technologies of winter lettuce in greenhouses were ranked by two multi-attribute decision making methods. Results of ranking for both methods, SAW and TOPSIS are shown. Alternatives were ranked by three different scenarios with different weight coefficients. The type of growing technology with combination of mulching + agro textile is the best ranked one according both methods and all scenarios. The SAW method showed more sensitivity on weight coefficients changes than TOPSIS.

Key words: multi-attribute ranking, SAW, TOPSIS, vegetable production, method

JEL: Q12, Q16

1 Grujica Vico Ph.D., Assistant Professor, University of East Sarajevo, Faculty of Agriculture, Vuka Karadžića no. 30, 71123 East Sarajevo, B&H, Phone: +387 65 728 323 E-mail: vicogrujica@yahoo.com
2 Aleksandra Govedarica Lučić Ph.D., Assistant Professor, University of East Sarajevo, Faculty of Agriculture, Vuka Karadžića 30, 71123 East Sarajevo, B&H, E-mail: sandraklepic@yahoo.com
3 Zoran Rajić Ph.D., Full Professor, University in Belgrade, Faculty of Agriculture, Nemanjina street no. 6, 11080 Zemun, Serbia, Phone: +381 11 261 53 15, E-mail: zorajic@agrif.bg.ac.rs
4 Radomir Bodiroga M.A., Ph.D. student, University of East Sarajevo, Faculty of Agriculture, Vuka Karadžića no. 30, 71123 East Sarajevo, B&H, Phone: +387 65 482 559 E-mail: radomir.bodiroga@gmail.com
5 Ivan Mičić M.A., Ph.D. student, University in Belgrade, Faculty of Agriculture, Nemanjina street no. 6, 11080 Zemun, Serbia, Phone: +381 11 261 53 15, E-mail: divanlav@gmail.com
6 Dr. sc. Silvija Zec Sambol, Ph.D., Faculty of Medicine, University of Rijeka, Nikole Tesle 1/1, 51000 Rijeka, Croatia, Phone: +381 62 867 45 98, E-mail: dr.zecss@yahoo.com
7 Marija Mičić M.A., Ph.D. student, University of Niš, Tehnological faculty Leskovac, The Boulevar of Liberation no. 124, 16000 Leskovac, Serbia, Phone: +381 62 867 45 98, E-mail: marija84micic@gmail.com
Introduction

The lettuce falls in the group yellow-green vegetable and is particularly significant in the nutrition due to its rich mineral-vitamin contents, especially during the winter period when there is no sufficient fresh vegetable on the market.

Anyhow, the winter production of lettuce is attributed by insufficient light but also usage of high quantities of nitrogen mineral manures which results in accumulation of the pestilent nitrate in the lettuce leaves. Accumulation of nitrate largely depends on the fertilizer (especially nitrogen) and climate conditions (Cometi et al., 2011; Proietti et al., 2004; Lazic et al., 2002). Besides nitrates, ascorbic acid concentration is also considered an important quality indicator in lettuces which is also influenced by both abiotic and biotic parameters (Cometti et al., 2011; Llorach et al., 2008). Vitamin C plays multiple roles in the human organism because it increases the organisms resistance to viruses and bacterial infections including allergies (Padayatty et al., 2003).

On the other side, the early fresh vegetable is quite expensive which makes it the most economical vegetable production which provides with planned harvest during the scarce offer on the market. Lettuce is the most popular vegetable according to the highest consumption rate and economic importance throughout the world (Coelho et al., 2005).

Considering the improtance of lettuce in nutrition and its economic justification, it is highly important to apply the corresponding special agro-technical measures in the production of this type. Manufacturing techniques affect growth rate, total yield, earlier yield and yield quality components (El–Shinawy and Gawish, 2006; El-Behairy et al., 2001).

By respecting many economic criteria as well as criteria of nutrition quality in the process of ranking various production technologies, a problem of mutli-criteria decisioning is formed. In solving problems of this type, the most applicable methods are MADM. Numerous (multi-criteria decision making) MCDM methods have been created and utilized over the last several decades (Velasquez and Hester, 2013).

The methods of mutliple attributive decisions is used in a numerous researches in the field of agriculture and similar fields. The problem spectrum in agriculture where the MADM could be applied is large. SAW method is used for a selection of strategy adaptation in SMEs (Domeova et al., 2006). Authors used 14 products upon three criterias whereas Matejcek and Brozova (2011) applied four types MADM for a selection of the optimal structure of vegetable production. Total of 9 various structures of production are used, 12 criteria and 4 MADM methods (AHP, ORESTE, TOPSIS, WSM). Eventually, the authors come to a compromise solution which took the first ranking in applying the three methods (AHP, TOPSIS, WSM), whereas under fourth method (ORESTE) the variant was placed second. In the literature, there are reseaches with combined methods „hard“ and „soft“ computing in the process of planning the vegetable production. Matejcek and Brozova (2012) used two types of mathematical model for multi-objective planning: multi-objective linear programming and multiple attribute analysis of variants. In first research stage they used multi-objective simplex algorithm with nine variables, twenty three constraints and
three criteria. In the second stage, for the process of choosing compromised variants, four multiple attribute analysis methods were used (AHP, ORESTE, TOPSIS, WSM). The combining multi-criteria decision-making methods can provide a whole new approach to decision analysis (Velasquez and Hester, 2013). SAW and Topsis methods, in combination with CP are applied for ranking a tractor (Blagojevic, et al., 2012). Within the paper, a final matrix is created, where the three methods are cited to be used as criteria. SAW is one of the most popular and most used MADM methods in certain research (Ginevicius, 2004, 2008, Ustinovicius, 2004, Vico at al., 2017).

Material and Methods

Raw data from the experimental greenhouse at the Faculty of Agriculture, University of East Sarajevo were used for ranking four different types of growing technology of winter lettuce. For this research, data from one experiment with three genotypes and four types of technology were used (for more information about this trial see Govedarica-Lucic et al., 2014). During the experiment, data was carefully collected in terms of: mechanization and labour force use, seed, fertilizers, rest of operating supplies, yield. For this research profit calculations were created for each one of the four certain technologies. Four certain growing technologies for production of winter lettuce for genotype SANTORO RZ were used as different alternatives. The trial included four variants of soil covering: control - planting on bare soil - A1, mulching before planting with PE - black foil - A2, agro textile - covering plants after planting with agro textile (17 g) - A3, a combination of mulching + agro textile – A4. Seven different criteria were used for this research (Table 1). Two groups of criteria were used: economic indicators and nutritional quality indicators. Four economic indicators were involved: C1. revenue as the difference between total income and total costs of production (except costs of labour force); C2. profit as difference between total income and total cost of production; C3. profitability as ratio between total income/total costs; C4. labour productivity as ratio between total amount of products / total amount of used labour hours. Three nutritional indicators were used: C5. contents of vitamin C (mg/100 g FW); C6. contents of nitrate (g/kg FW); C7. contents of total nitrogen (%). The alternatives were ranked through two MADM method: SAW and TOPSIS.

Results and Discussion

In general, every problem of multi-criteria analyses can be solved based upon three approaches: 1. problem in ranking- with intention to rank the group of alternatives 2. problem due to selection of one alternative- only one alternative is chosen from the group – „the best“ 3. problem due to selection of many alternatives – a sub-group from the group of alternatives is chosen. According to this approach, the number of alternatives could be determined in advance, but some conditions can also be set for each separate alternative to accomplish in order to be chosen. In this research, the approach according to which all the alternatives are ranked for application of the two MADM methods: SAW and TOPSIS is chosen.
The SAW method

The SAW is one of the simplest, most widely used multi-criteria evaluation method and the most popular MADM method (Polednikova, 2014). This method requires from the decision maker to allocate weight coefficients upon the applied criteria. SAW method is particularly beneficial when all the criteria are numeric values, like the financial indicators. SAW method consists of few main steps. The general form of SAW method is:

\[
R = \begin{bmatrix}
A_1 & x_{11} & \cdots & x_{1m} \\
A_2 & x_{21} & \cdots & x_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
A_n & x_{n1} & \cdots & x_{nm}
\end{bmatrix}
\]

where:

- \( A_n \) – alternatives (certain types of growing technologies)
- \( C_n \) – criteria (seven economic and nutrient quality indicators)
- \( w_m \) – weight coefficients for criteria
- \( x_{ij} \) – original values

The normalization of criteria is made as following:

For criteria which are maximized:

\[
\tau_{ij} = \frac{x_{ij} - x_{j}^{*}}{x_{j}^{*} - x_{j}^{**}}
\]

For criteria which are minimized:

\[
\tau_{ij} = \frac{x_{j}^{**} - x_{ij}}{x_{j}^{**} - x_{j}^{*}}
\]

where \( x_{j}^{*} \) is the best value of chosen criteria for all alternatives and \( x_{j}^{**} \) is the worst value.

In the next step normalized matrix is multiplied by the vector of weight coefficients:

\[
\begin{bmatrix}
\tau_{11} & \tau_{12} & \cdots & \tau_{1m} \\
\tau_{21} & \tau_{22} & \cdots & \tau_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
\tau_{n1} & \tau_{n2} & \cdots & \tau_{nm}
\end{bmatrix} \times \begin{bmatrix}
w_1 \\
w_2 \\
\vdots \\
w_m
\end{bmatrix}
\]

and the final value is calculated through:

\[
S_i = \sum_{j=1}^{m} w_j \tau_{ij}
\]

The best alternative is of the biggest value.
The TOPSIS method ranks the alternatives according to their distances from the ideal and the negative ideal solution. This method was first developed by Hwang and Yoon (Hwang and Yoon, 1981). Matejcek and Brozova (2011) present four steps within TOPSIS algorithm (according Hwang & Yoon, 1981). The steps are: 1. "the ideal solution is formed as a composite of the best performance values exhibited (in the decision matrix) by any alternative for each attribute. The negative-ideal solution is the composite of the worst performance values. 2. Proximity to each of variants to ideal and negative ideal solution is measured in the Euclidean sense (e.g., square root of the sum of the squared distances along each axis in the “attribute space”), with optional weighting of each attribute. 3. Relative closeness of variants to the ideal solution is defined as the ratio of distance from negative ideal solution and sum of distance from ideal and distance from negative-ideal solution. 4. Selection of the best variant is based on the highest relative closeness."

The procedure of solving problems through multi-criteria ranking by applying the TOPSIS method via six steps are given in Opricovic and Tzeng (2004):

1. "Calculate the normalized decision matrix.

\[ r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{J} f_{ij}^2}} \]

where: \( r_{ij} \) – normalized values; \( j=1,\ldots,J; i=1,\ldots,n \)

2. Calculate the weighted normalized decision matrix. \( \nu_{ij} = w_i r_{ij} \)

where \( \nu_{ij} \) weighted normalized values; \( \nu_{ij} \) is weight of the \( i \)th attribute. \( j=1,\ldots,J; i=1,\ldots,n. \)

3. Determine the ideal and negative-ideal solutions.

\[ A^* = \{\nu_1^*, \ldots, \nu_n^*\} = \left\{ \left( \max_j v_{ij} \right)_{i \in I'}, \left( \min_j v_{ij} \right)_{i \in I''} \right\} \]

\[ A^- = \{\nu_1^-, \ldots, \nu_n^-\} = \left\{ \left( \min_j v_{ij} \right)_{i \in I'}, \left( \max_j v_{ij} \right)_{i \in I''} \right\} \]

Where \( I' \) is associated with benefit criteria, and \( I'' \) is associated with cost criteria.

4. Through n-dimenzional Euclidean distance calculate the separation of each alternative from the ideal solution:
5. Calculate the relative closeness to the ideal solution. The relative closeness of the alternative \(a_j\) with respect to \(A^*\) is defined as
\[ C_j^* = \frac{D_j^-}{(D_j^- + D_j^+)} , \quad j = 1, ..., J \]

6. Rank the preference order.

**Ranking alternatives**

For ranking certain grow technologies SAW and TOPSIS MADM methods were used. Four alternatives and seven criteria were used. The characteristics of criteria are shown in Table 1. Five criteria should be maximized and two criteria should be minimized. All criteria are quantitative values.

**Table 1. Specification of criteria**

| Criteria | Unit               | Criteria group | to be max | to be min |
|----------|--------------------|----------------|-----------|-----------|
| C1       | BAM/kg             | Economical     | +         |           |
| C2       | BAM/kg             | Economical     | +         |           |
| C3       | n/a                | Economical     | +         |           |
| C4       | n/a                | Economical     | +         |           |
| C5       | mg/100 g FW        | Quality        | +         |           |
| C6       | g/kg FW            | Quality        |           | +         |
| C7       | %                  | Quality        |           | +         |

**Source:** Work of author

Two economic criteria are absolute values representing effectiveness (revenue and profit), while other two criteria are relative values representing economic efficiency in vegetable production (labour productivity and profitability).
Table 2. The raw data for certain alternatives

| Alternative | C1 (BAM/kg) | C2 (BAM/kg) | C3   | C4   | C5 (mg/100 g FW) | C6 (g/kg FW) | C7 (%) |
|-------------|-------------|-------------|------|------|------------------|--------------|--------|
| A1          | 1.80        | 1.15        | 1.63 | 3.90 | 18.65            | 2196.33      | 3.85   |
| A2          | 1.86        | 1.37        | 1.84 | 5.09 | 18.45            | 2412.83      | 3.95   |
| A3          | 1.88        | 1.43        | 1.91 | 5.53 | 27.03            | 2526.24      | 4.07   |
| A4          | 2.12        | 1.75        | 2.39 | 6.76 | 26.79            | 2519.63      | 3.99   |

Source: Work of author

Certain alternatives show differences between values within some criteria. For example, alternative A4 is the best according to the economic criteria, but the worst according C5. Alternative A1 is the worst according to all economic criteria, but it is the best according all nutritional quality criteria.

For unique ranking some MADM methods are needed to be used. Within this research we chose the two most frequently used methods: SAW and TOPSIS.

Before making the calculation, the weight coefficients must be defined.

Table 3. Weight coefficients for certain models

| Model | Economic criteria | Nutritional quality criteria | Total for group | C5 | C6 | C7 | Total for group |
|-------|-------------------|------------------------------|----------------|----|----|----|----------------|
|       | C1    | C2    | C3    | C4    |     |     |     |     |
| S1    | 0.125 | 0.125 | 0.125 | 0.125 | 0.500 | 0.167 | 0.167 | 0.167 | 0.500 |
| S2    | 0.167 | 0.167 | 0.167 | 0.167 | 0.667 | 0.111 | 0.111 | 0.111 | 0.333 |
| S3    | 0.083 | 0.083 | 0.083 | 0.083 | 0.333 | 0.222 | 0.222 | 0.222 | 0.667 |

Source: Work of author

In the first scenario (S1) economic criteria and nutritional quality criteria have the same values of weight coefficients, 0.500 for both. The second scenario (S1) favors the economic criteria. Economic criteria (0.667 vs 0.333 for Nutritional quality criteria). In the third scenario (S1) values are reciprocal (table 3)

Table 4. Results of ranking

| Alternative | SAW | | | TOPSIS | |
|-------------|-----|-----|------|--------|---|
|              | S1  | Order | Value | S2    | Order | Value | S3    | Order |
| A1          | 0.33722 | 3     | 0.22481 | 4     | 0.44962 | 2     |
| A2          | 0.30402 | 4     | 0.30656 | 3     | 0.30148 | 4     |
| A3          | 0.37354 | 2     | 0.38695 | 2     | 0.36014 | 3     |
| A4          | 0.72595 | 1     | 0.81730 | 1     | 0.63460 | 1     |

Source: Work of author
The type of growing winter lettuce which uses a combination of mulching with agro-textile (A4) is the best alternative (table 4.). The economic parameters of A4 are much higher than every other alternative. The difference between A4 and other alternatives is the lowest in S3 for both SAW and TOPSIS methods. The A4 has high values for C6 and C7, which is the poor, but good economic performances are contributing for the best global score. The A2 is a type of growing technology with the worst global score for both methods.

Data in Table 4 shows that SAW method is more sensitive on weight coefficients changes, than TOPSIS method. The used two MADM methods in this research can be good as terminated tools not only in agro-economic research, but also in other studies in the field of agriculture.

**Conclusion**

The production of winter lettuce in greenhouses can be realized based on many technologies, upon which various production results are obtained. The choice of the most applicable technology is a process where many attributes should be respected. By applying in that process many economic criteria as well as criteria of nutrition quality, a multi-attribute problem is achieved which could be solved through some of the MADM methods. By applying of SAW and TOPSIS methods a close ranking of the alternatives is obtained. There is a wide spectrum of problems in agricultural production which are in fact a multi-criteria task and could be solved by application of some of the MADM methods.

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PRISTUP VIŠEATRIBUTIVNE PROCENE U PROIZVODNJI POVRĆA

Grujica Vico, Aleksandra Govedarica-Lučić, Zoran Rajić, Radomir Bodiroga, Ivan Mičić, Silvija Zec Sambol, Marija Mičić

Sažetak

U radu je korišćeno dvije vrste kriterijuma ekonomske efektivnosti i dvije vrste kriterijuma ekonomske efikasnosti, kao i tri indikatora nutritivnog kvaliteta za rangiranje različitih tehnologija gajenja zimskih salata. Korišćenjem dvije metode višeatributivnog odlučivanja, izvršeno je rangiranje četiri različite tehnologije gajenja zimskih salata u zaštićenom prostoru. Prikazani su rezultati rangiranja na osnovu oba korišćena metoda, SAW i TOPSIS. Alternative su rangirane kroz tri scenarija koji se razlikuju po težinskih koeficijentima. Tehnologija proizvodnje koja podrazumijeva malč+agrotekstil pokazala se kao najbolja alternativa pri korišćenju oba metoda i svih scenarija. SAW metod se pokazao kao senzitivniji na promjene težinskih koeficijenata u odnosu na TOPSIS metod.

Ključne reči: višeatributivno odlučivanje, SAW, TOPSIS, proizvodnja povrća, metod

8 Doc. Dr Grujica Vico, Univerzitet u Istočnom Sarajevu, Poljoprivredni fakultet, Vuka Karadžića br. 30, 71123 Istočno Sarajevo, BiH, Telefon: +387 57 340 401, E-mail: vicogrujica@yahoo.com
9 Doc. Dr Aleksandra Govedarica Lučić, Univerzitet u Istočnom Sarajevu, Poljoprivredni fakultet, Vuka Karadžića br. 30, 71123 Istočno Sarajevo, BiH, Telefon: +387 57 340 401, E-mail: sandraklepic@yahoo.com
10 Redovni profesor, dr Zoran Rajić, Univerzitet u Beogradu, Poljoprivredni fakultet, Nemanjina ulica br. 6, 11080 Zemun, Srbija, Telefon: +381 11 261 53 15, E-mail: zorajic@agrif.bg.ac.rs
11 Mr Radomir Bodiroga, doktorant, Univerzitet u Istočnom Sarajevu, Poljoprivredni fakultet, Vuka Karadžića br. 30, 71123 Istočno Sarajevo, BiH, Telefon: +387 55 250 122 E-mail: radomir.bodiroga@gmail.com
12 Mr Ivan Mičić, doktorant, Univerzitet u Beogradu, Poljoprivredni fakultet, Nemanjina ulica br. 6, 11080 Zemun, Srbija, Telefon: +381 62 973 11 58, E-mail: divanlav@gmail.com
13 Dr. sc. Silvija Zec Sambol, dr med. Medicinski fakultet Sveučilišta u Rijeci, Nikole Tesle 1/I, 51000 Rijeka, Croatia, Telefon: +381 62 867 45 98, E-mail: dr.zecss@yahoo.com
14 Mr Marija Mičić, doktorant, Univerzitet u Nišu, Tehnološki fakultet u Leskovcu, Bulevar Oslobodjenja br. 124, 16000 Leskovac, Srbija, Telefon: +381 62 867 45 98, E-mail: marija84micic@gmail.com
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