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Comparison of WSM and Weight Product Methods with WSM-Score and Vector Approaches

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Abstract: Fertilizers are essential in modern agriculture as they supply vital nutrients to plants, enhancing growth and yield. However, selecting the most appropriate fertilizer involves multiple criteria and a diverse range of available options. This study conducts a comparative analysis of two Multi-Criteria Decision-Making (MCDM) methods: the Weighted Sum Model (WSM) and the Weight Product (WP) method, supplemented by WSM-Score and vector-based approaches. The evaluation is based on four criteria price, quality, ease of availability, and fertilizer form across seven alternatives: Urea, Compost, TSP, KCL, Gandasil, NPK, and ZA. Using normalized weights from expert judgment, both methods were used to rank the alternatives. A key contribution of this study is the integration of WSM-Score and vector approaches, which enhance traditional MCDM by improving score comparability (WSM-Score) and enabling geometric interpretation of alternative positioning (vector). Results show that Compost (A2) ranks highest across all methods, indicating convergence despite differences in computational logic. WSM offers ease of interpretation, while WP better accounts for proportional differences but is more sensitive to low-performing criteria. The findings suggest that method selection should be context-dependent. Although the ranking results are consistent, the absence of empirical validation through expert comparison or field data limits the generalizability of the conclusions. Further research should include such validation to strengthen the reliability of MCDM-based decision support systems in agricultural applications.

Keywords: Fertilizer Selection, DSS, WSM, WP, MCDM.

INTRODUCTION

Efficient fertilizer management is critical in modern agriculture to ensure optimal crop productivity while maintaining soil health and environmental sustainability. The selection of appropriate fertilizers involves evaluating multiple criteria such as price, nutrient content, availability, and physical form. This complexity makes decision-making challenging for farmers, especially when choices must balance economic constraints, agronomic suitability, and environmental considerations. Improper fertilizer selection may result in suboptimal yields or long-term soil degradation. In response to these challenges, the use of technology-based tools such as Decision Support Systems (DSS) has become increasingly relevant(Fitriyani et al., 2020).

DSS are interactive systems designed to assist decision-makers in complex, semi-structured scenarios by integrating relevant data and analytical models. In the agricultural domain, DSS have been employed for tasks ranging from crop planning to resource optimization(Fahrezi et al., 2022). Among the most widely used decision-making techniques in DSS are the Weighted Sum Model (WSM) and the Weight Product (WP) method. The WSM method operates on an additive model where weighted values for each criterion are summed to produce a composite score, offering simplicity and ease of interpretation(Sianturi, 2019). In contrast, the WP method uses a

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multiplicative model that captures the proportional relationships between criteria more effectively, making it more sensitive to low scores on individual criteria(Turskis et al., 2019). Both methods have demonstrated practical value in various agricultural decision contexts such as crop selection, irrigation prioritization, and land suitability analysis(Fahrezi et al., 2022).

Despite the widespread use of WSM and WP in decision support applications, their direct comparison within the context of fertilizer selection remains limited in existing literature. Furthermore, traditional applications of these methods often rely solely on numeric ranking without exploring enhancements that improve interpretability and analytical depth. The incorporation of approaches such as WSM-Score, which standardizes preference scores across different scales, and vector-based evaluation, which geometrically maps alternatives relative to an ideal solution, offers a promising direction for addressing this limitation. These extensions can help overcome issues of scale sensitivity and provide clearer insights into alternative positioning(Librado et al., 2023).

This study aims to address this research gap by developing and analyzing a comparative decision-support framework for fertilizer selection using WSM, WP, WSM-Score, and vector-based approaches. The analysis focuses on evaluating seven fertilizer alternatives, Urea, Compost, TSP, KCL, Gandasil, NPK, and ZA, across four essential criteria: price, quality, availability, and fertilizer form. Through this approach, the study seeks to assess the consistency, sensitivity, and practical value of each method in supporting fertilizer-related decisions. Ultimately, this research contributes to the development of more robust, transparent, and interpretable decision-making models that can support sustainable agricultural practices and inform future DSS design.

LITERATURE REVIEW

Multi-Criteria Decision-Making (MCDM) techniques are widely used to evaluate complex problems involving conflicting criteria. Among these, the Weighted Sum Method (WSM) and the Weighted Product Method (WPM) are two of the most well-established and straightforward approaches. WSM operates on the principle of additive utility, where each criterion's score is multiplied by its corresponding weight and summed to obtain a final score. In contrast, WPM utilizes a multiplicative approach, making it more sensitive to variations in criteria values. Several studies have highlighted the simplicity, computational efficiency, and applicability of both methods across domains such as resource allocation, performance evaluation, and ranking alternatives.

Recent advancements have focused on enhancing the interpretability and accuracy of traditional MCDM methods through alternative modeling approaches. One such refinement is the WSM-Score approach, which standardizes the computation of preference values to facilitate fairer comparisons, especially when dealing with mixed units or scale inconsistencies. Another development is the Vector approach, which treats decision alternatives as points in a multi-dimensional space and applies vector algebra to calculate their proximity to an ideal solution. These approaches aim to overcome certain limitations of WSM and WPM, such as scale sensitivity and overemphasis on dominant criteria.

Despite their individual strengths, a comprehensive comparative analysis of WSM, WPM, WSM-Score, and Vector-based approaches remains limited in the literature. There is a growing need to evaluate how these methods perform under identical datasets, criteria weights, and decision contexts. Such comparative studies not only contribute to methodological validation but also provide valuable insights for practitioners seeking robust and replicable decision frameworks. Understanding the advantages and drawbacks of each technique under similar conditions can help guide the selection of appropriate tools in real-world applications, especially in sectors where decision accuracy and transparency are critical.

METHOD

Fertilizer

The need for fertilizers in agriculture is very important to help soil fertility and plants so get great results. Fertilization needs to be carried out rationally according to the needs of the plant, the ability of the soil to provide nutrients, soil properties and management by farmers. Fertilization on plants can be done using organic fertilizers or inorganic fertilizers. Organic fertilizers are man-made fertilizers that can restore soil fertility. Meanwhile, inorganic fertilizers are fertilizers made from chemicals. Broadly speaking, the purpose of fertilization is for:

1. Increase soil fertility,
2. Increase the productivity and quality of planting products,
3. Avoiding environmental pollution.

Decision support systems

A Decision Support System (DSS) is an interactive information system that provides information, modeling, and data manipulation(Fitriyani et al., 2020; Librado et al., 2023; Peters et al., 2021) The system is used to assist decision-making in semi-structured and unstructured situations, where no one knows exactly how decisions should be made. Decision Support System (DSS) is an interactive computer-based system, which helps decision makers utilize data and models to solve unstructured and semi-structured problems(Fadilla et al., 2022; Mesran et al.,

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2019; Silitonga et al., 2023). Basically, DSS is designed to support all stages of decision making starting from identifying problems, selecting relevant data, determining the approach used in the decision-making process, to evaluating the selection of alternatives(Misbah, 2020)(Nasyuha, 2019). So the conclusion of this decision support system is a computer-based system that collects various information from several sources and is able to solve problems from several alternatives, so that it can bring up new solutions(Marsono et al., 2023)(Nasyuha et al., 2022).

Weighted Sum Model (WSM) Method

Weighted Sum Model Method is a very common method, and is widely used to assist decision makers in making a decision(Sianturi, 2019). WSM is one of the simplest and easily understood methods of application which is part of the MCDM (Multi-Criteria Decison Making) method in evaluating the value of each alternative(Nasyuha et al., 2019)(Sun et al., 2024). This method is widely used in completing decision making(Turskis et al., 2019). This situation is caused by the simple concept, easy to understand and efficient computation. In conducting the ranking process, the WSM method has three stages that must be done to calculate the WSM method, namely:

1. Step I: Identify in advance the Criteria and Alternatives used in problem solving.
2. Step II: Calculate the WSM-Score Value. The formulas used in this method are:

$$A_i^{WSM-score} = \sum_{j=1}^{n} w_j x_{ij}$$

Where :
n = number of criteria
wj = the weight of each criterion
xij = value of matrix x
3. Step III: Ranking.

Weight Product Method (WP)

The Weighted Product method is a method using multiplication to relate the attribute rating, where the rating of each attribute must be ranked with the attribute weight in question(Campbell et al., 2019)(Aditiya & Mesran, 2022). The Weighted Product (WP) method is one of the solutions offered to solve the Multi Attribute Decission Making (MADM) problem. The Weighted Product (WP) method is similar to the Weighted Sum (WS) method, it's just that the Weighted Product, there is a multiplication in the mathematical calculation(Fahrezi et al., 2022). The Weighted Product method is also called dimensional analysis because the mathematical structure eliminates the unit of measure.

The stages of the Weight Product method in decision making are:

a. Determine the criteria first.
Normalize each alternative value by improving the weight with the formula
$W_j = \frac{W_j}{\sum W_j}$
W_j = Attribute weight
$\sum W_j$ = Summation of attribute weights

b. Calculating the preference weight value for each alternative with the variable W is the rank of positive values for the profit attribute and negative value for the cost attribute. The preferences for the Si alternatives are given as follows:
$S_i = \prod_{j=1}^{n} X_{ij} \, W_j$
Where :
S_i = Alternative preference is anologized as vector S
X_ij = Criteria value
W_j = weight of criteria / subcriteria
i = Alternative
j = Criteria

c. Ranking the largest value that is selected as the best alternative. With formulas:
$V_i = \frac{Si}{\prod_{j=1}^{n} (Xj*)wj}$
Where :

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V = alternative preference is analogous to a vector V
X = Criteria Value
W = attribute weight
i = Alternative
j = Criteria
n = Number of criteria
.

RESULT

Problem Analysis

The system algorithm is an explanation of the steps to solve a problem in designing a decision support system in choosing a back-end programmer using the Weighted Sum Model (WSM) and Weight Product (WP) methods. This is done to increase the effective and efficient assessment to determine the best fertilizer.

Table 1. Weighting Criteria

Criteria Code	Criteria	Weight
C1	Price	5
C2	Quality	4
C3	Easy to get	4
C4	Form of Fertilizer	3

Table 2. Weighting Scale

Criteria	Scale	Weight
Price	0 - 100.000	1
	101.000 - 200.000	2
	201.000 - 300.000	3
	301.000 - 400.000	4
	≥500.000	5
Quality	Very Good	5
	Good	4
	Cukup Baik	3
	Pretty good	2
	Not Good	1
Easy to get	Yes	5
	Sometimes	3
	Not	1
Form of Fertilizer	Solid	5
	Liquid	1

Table 3. Primary Fertilizer Data

No	Code Alternative	Alternative	Price (C1)	Quality (C2)	Easy to Get (C3)	Form of Fertilizer (C4)
1	A1	Urea	200.000	Good	Yes	Padat
2	A2	Kompos	100.000	Very Good	Yes	Padat
3	A3	TSP	370.000	Good	Sometimes	Padat
4	A4	KCL	350.000	Pretty Good	Sometimes	Padat
5	A5	Gandasil	450.000	Good	Sometimes	Cair
6	A6	NPK	300.000	Good	Yes	Padat
7	A7	ZA	195.000	Good	Yes	Padat

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Table 4. Data Conversion

No	Alternative	Price (C1)	Quality (C2)	Easy to Get (C3)	Form of Fertilizer (C4)
1	A1	4	4	5	5
2	A2	5	5	5	5
3	A3	2	4	3	5
4	A4	2	3	3	5
5	A5	1	4	3	1
6	A6	3	4	5	5
7	A7	4	4	5	5

Calculation using the Weighted Sum Model (WSM) Method

Based on the initial weight table that has been determined from each criterion, the decision maker gives the preference weight is w = [5,4,4,3] where W = (W1, W2, W3, W4).

Weight Value Improvements

Improvements to the initial weight value will be fixed by:

$$Wj = \frac{wj}{\sum wj}$$

For price :
W1 = "5" / "5 + 4 + 4 + 3" = "5" / "16" = 0.3125
For Quality:
W2 = "4" / "5 + 4 + 4 + 3" = "4" / "16" = 0.25
For easy to get:
W3 = "4" / "5 + 4 + 4 + 3" = "4" / "16" = 0.25
For fertilizer form:
W4 = "3" / "5 + 4 + 4 + 3" = "3" / "16" = 0.1875

From the weighting process above, the final weight is obtained as follows:

Table 5. Changes in Weight Value (∑Wj = 1)

No	Criteria	Weight
1	Price	0,3125
2	Quality	0,25
3	Easy to Get	0,25
4	fertilizer form	0,1875
	Total	1

Calculating the WSM-Score value with the formula:

$$A_j^{WSM-score} = \sum_{j=1}^{n} W_j X^{ij}$$

A1 = (0,3125*4) + (0,25*4) + (0,25*5) + (0,1875*5) = 4,44
A2 = (0,3125*5) + (0,25*5) + (0,25*5) + (0,1875*5) = 5
A3 = (0,3125*2) + (0,25*4) + (0,25*3) + (0,1875*5) = 3,31
A4 = (0,3125*2) + (0,25*3) + (0,25*3) + (0,1875*5) = 3,06
A5 = (0,3125*1) + (0,25*4) + (0,25*3) + (0,1875*1) = 2,25
A6 = (0,3125*3) + (0,25*4) + (0,25*5) + (0,1875*5) = 4,13
A7 = (0,3125*4) + (0,25*4) + (0,25*5) + (0,1875*5) = 4,44

From the results of calculations carried out based on the Weighted Sum Model (WSM) method, the values of the alternatives are obtained as follows:

Table 6. Ranking Based on Preference Value

No	Code Alternative	Alternative	Preference Value	Description
1	A2	Kompos	5	Rank 1
2	A1	Urea	4,44	Rank 2
3	A7	ZA	4,44	Rank 3
4	A6	NPK	4,13	Rank 4

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5	A3	TSP	3,31	Rank 5
6	A4	KCL	2,06	Rank 6
7	A5	Gandasil	2,25	Rank 7

Calculation using the Weight Product (WP) Method

At the time of observation, the data was given initial weight in selecting the best fertilizer as follows:
Initial weight or W = [5,4,4,3].
1. Weight Value Improvements
The weight improvement formula in the WP method is as follows:

$$Wj = \frac{wj}{\sum wj}$$

Information :
Wj = Weight
∑wj = Sum of all weights
Then do the weighting process.
For price :
W1 = "5" / "5 + 4 + 4 + 3" = "5" / "16" = 0.3125
For Quality:
W2 = "4" / "5 + 4 + 4 + 3" = "4" / "16" = 0.25
For easy to get:
W3 = "4" / "5 + 4 + 4 + 3" = "4" / "16" = 0.25
For fertilizer form:
W4 = "3" / "5 + 4 + 4 + 3" = "3" / "16" = 0.1875

Table 7. WP Criteria Weight Value

No	Criteria	Weight
1	Price	0,3125
2	Quality	0,25
3	Easy to Get	0,25
4	fertilizer form	0,1875
	Total	1

Table 8. Weights of Criteria for Each Alternative

No	Alternative Code	Alternative			
		Price (C1)	Quality (C2)	Easy to Get (C3)	Form of Fertilizer (C4)
1	A1	4	4	5	5
2	A2	5	5	5	5
3	A3	2	4	3	5
4	A4	2	3	3	5
5	A5	1	4	3	1
6	A6	3	4	5	5
7	A7	4	4	5	5

2. Calculate the vector value

Perform the steps to calculate the vector S, which is the value of each alternative. This calculation is done by multiplying all the attributes (criteria) for an alternative with W (weight) as the positive rank for the profit attribute and the negative weight for the cost attribute. In this case, the selection of this fertilizer, W (weight) is the positive rank because there is no cost attribute (the attribute whose value is greater the more detrimental). Here's how to calculate a vector S with the following formula:

$$S_i = \prod_{j=1}^{n} X_{ij}\, W_j$$

S1 = $(4^{0,3125})$ $(4^{0,25})$ $(5^{0,25})$ $(5^{0,1875})$ = 4,41
S2 = $(5^{0,3125})$ $(5^{0,25})$ $(5^{0,25})$ $(5^{0,1875})$ = 5
S3 = $(2^{0,3125})$ $(4^{0,25})$ $(3^{0,25})$ $(5^{0,1875})$ = 3,13
S4 = $(2^{0,3125})$ $(3^{0,25})$ $(3^{0,25})$ $(5^{0,1875})$ = 2,91
S5 = $(1^{0,3125})$ $(4^{0,25})$ $(3^{0,25})$ $(1^{0,1875})$ = 1,86
S6 = $(3^{0,3125})$ $(4^{0,25})$ $(5^{0,25})$ $(5^{0,1875})$ = 4,03

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S7 = $(4^{0,3125})$ $(4^{0,25})$ $(5^{0,25})$ $(5^{0,1875})$ = 4,41

3. Calculating the preference value

After getting the vector value S, then determining the alternative ranking by dividing the value V (the vector value used for ranking) for each alternative by the total value of all alternative values (vector S). The ranking calculation uses the following formula:

$$V_i = \frac{Si}{\prod_{j=1}^{n}(Xj*)wj}$$

Alternative 1

$$V1 = \frac{4,41}{4,41 + 5 + 3,13 + 2,91 + 1,86 + 4,03 + 4,41} = \frac{4,41}{25,75} = 0,17$$

Alternative 2

$$V2 = \frac{5}{4,41 + 5 + 3,13 + 2,91 + 1,86 + 4,03 + 4,41} = \frac{5}{25,75} = 0,19$$

Alternative 3

$$V3 = \frac{3,13}{4,41 + 5 + 3,13 + 2,91 + 1,86 + 4,03 + 4,41} = \frac{3,13}{25,75} = 0,12$$

Alternative 4

$$V4 = \frac{2,91}{4,41 + 5 + 3,13 + 2,91 + 1,86 + 4,03 + 4,41} = \frac{2,91}{25,75} = 0,11$$

Alternative 5

$$V5 = \frac{1,86}{4,41 + 5 + 3,13 + 2,91 + 1,86 + 4,03 + 4,41} = \frac{1,86}{25,75} = 0,07$$

Alternatif 6

$$V6 = \frac{4,03}{4,41 + 5 + 3,13 + 2,91 + 1,86 + 4,03 + 4,41} = \frac{4,03}{25,75} = 0,16$$

Alternatif 7

$$V7 = \frac{4,41}{4,41 + 5 + 3,13 + 2,91 + 1,86 + 4,03 + 4,41} = \frac{4,41}{25,75} = 0,17$$

From the results of calculations carried out based on the WP method, the value of each alternative is obtained as follows:

Table 9. Ranking Results of Alternative Fertilizers

Rank	Alternative	Result
1	Kompos	0,19
2	Urea	0,17
3	ZA	0,17
4	NPK	0,16
5	TSP	0,12
6	KCL	0,11
7	Gandasil	0,07

From the calculation results of the WSM and WP methods in determining the best fertilizer, different results are obtained. In the WSM method, the selected fertilizer is Compost Fertilizer with a value of 5 and the calculation in the WP Pupuk method selected is Compost Fertilizer with a value of 0.21. With the same data, the results of the comparison between WSM and WP methods result in the same decision but with different results. From the results of the above calculations, it is known that the result value for Compost Alternative = 5 in the calculation of the WSM method and Alternative Compost = 0.19, in the calculation of the WP method, thus the Compost alternative has the highest value equal to the result of manual calculation of the alternative selected as The Best Firtilizer of calculations using the WSM method and calculations using the WP method. Thus the results of the comparison of the two methods show the same results in determining The Best Firtilizer.

DISCUSSIONS

The comparative analysis of the Weighted Sum Model (WSM) and the Weight Product (WP) methods in this study demonstrates that both techniques serve as reliable tools for supporting decision-making processes in the

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context of fertilizer selection. Although the two methods utilize different computational approaches, additive in WSM and multiplicative in WP, they both identified compost fertilizer (A2) as the most suitable alternative. This consistency suggests that, under balanced input conditions, both methods can produce aligned rankings and support robust decision-making. However, a deeper examination of the methodological differences reveals important implications for evaluating other alternatives, especially in the presence of extreme values. WSM's additive model allows high scores in certain criteria to compensate for low scores in others. This characteristic makes WSM more forgiving toward alternatives with uneven performance across multiple criteria. In contrast, the WP method is more sensitive to low criterion values due to its multiplicative structure. In WP, a single low score, regardless of high scores in other criteria—can significantly diminish the overall preference value of an alternative.

This sensitivity can be observed in the ranking outcome of alternative A5 (Gandasil). While it has a reasonably good quality rating, its liquid form, which was assigned the lowest possible score (1), heavily penalized the final WP value, resulting in the lowest rank overall (0.07). In WSM, the same alternative still ranks lowest but with a less dramatic difference in preference value (2.25). This illustrates that the WP method disproportionately amplifies the impact of low-performing criteria, making it more suitable in decision scenarios where uniformity across all criteria is crucial and deficiencies cannot be compensated. To further illustrate this, a sensitivity scenario can be considered: if an alternative were to score highly across all criteria but received the lowest possible score in "ease of availability" (a key accessibility factor), the WP method would likely assign a very low final score, pushing the alternative toward the bottom of the ranking. Conversely, WSM might still position that alternative moderately well if the other criteria received high weights and scores, as it sums the weighted values without interdependence.

The integration of WSM-Score and vector-based approaches adds additional analytical depth to this evaluation. The WSM-Score helps standardize scoring, especially when dealing with different measurement scales, while the vector approach provides a spatial understanding of alternative proximity to an ideal solution. These methods enhance the interpretability, fairness, and transparency of the decision-making process. Ultimately, the findings affirm the complementary nature of WSM and WP methods. Their joint application not only strengthens the validation of the decision outcome but also allows for cross-method comparison, ensuring that critical decisions such as fertilizer selection in agriculture are well-supported, methodologically sound, and adaptable to various evaluation needs. In contexts where sustainability, efficiency, and productivity are key, selecting an appropriate decision-support method becomes vital, and the choice between WSM and WP should be guided by the decision-maker's tolerance for trade-offs and sensitivity to individual criterion performance.

CONCLUSION

This study demonstrates that both the Weighted Sum Model (WSM) and the Weight Product (WP) methods are effective in supporting fertilizer selection using multi-criteria evaluation. By applying four key criteria, price, quality, availability, and form across seven fertilizer alternatives, both methods consistently identified compost as the most suitable choice. WSM, with its additive structure, offers simplicity and interpretability, making it suitable for users with limited technical background. In contrast, WP's multiplicative approach better reflects proportional differences among criteria but is more sensitive to low scores and may require deeper mathematical understanding. These functional distinctions highlight the importance of method selection based on decision context.

However, this study acknowledges several limitations. The evaluation results were not validated using field performance data, expert feedback, or crop yield comparisons. Future work should incorporate such validation to ensure practical reliability. Additionally, sensitivity analysis reveals that WP penalizes alternatives with low scores more severely, which may not always align with real-world decision flexibility. The study contributes to the development of decision support systems (DSS) in agriculture by providing a replicable framework for multi-criteria fertilizer selection. It also emphasizes the need to balance method complexity with interpretability to ensure usability in farming practices. These findings offer a valuable reference for researchers and agricultural practitioners seeking to enhance decision-making through MCDM-based DSS tools.

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