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Empowering Farmers: Informed Crop Selection through TOPSIS-AHP SAATY Methodology

Dr. S. Aruna [1], Dr. L. V. Nandakishore [2]

[1]Assistant Professor, Department of Computer Science, Agurchand Manmull Jain College, Meenambakkam, Chennai.

[2]Professor, Department of Mathematics, Dr. M.G.R. Educational and Research Institute, Chennai.

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KEYWORDS
Crop Selection, Multiple-criteria decision-making (MCDM), TOPSIS, SAATY.

ABSTRACT:
This study adopts the TOPSIS-AHP SAATY methodology to offer farmers a systematic and evidence-based framework for crop selection. The utilization of the TOPSIS-AHP methodology not only enables farmers to gain insights into optimal crop selection strategies but also enhances their ability to achieve agricultural objectives effectively. By providing a robust and scientifically grounded approach, farmers can make informed decisions that lead to increased productivity, profitability, and sustainability in their farming endeavors. Thus, the application of these methodologies translates into tangible benefits for farmers, enabling them to navigate the complexities of crop selection with greater confidence and precision. The five crops Tomato, Chilli, Cabbage, Bhendi, and Brinjal are considered for this study. By evaluating multiple criteria encompassing cost of cultivation, yield, net income, and market price the TOPSIS method enables structured ranking of crop alternatives, while the AHP SAATY method computes weights, ensuring decision-making model consistency and reliability. Cabbage emerges as the optimal crop choice, with a maximum performance score of 0.772. The utilization of TOPSIS-AHP methodology furnishes farmers with a robust and scientifically grounded approach to optimize crop selection strategies, facilitating the attainment of agricultural objectives.

INTRODUCTION

India is a country where agriculture is one of the major professions and it becomes vital to apply scientific methods to decide which crops can be grown in the order of ranking. However importance should be given to all crops since they provide natural nutrition for the health. Multiple criterion decision making is a difficult task. It may be necessary to take a decision to find the best place to set up a business, home, selecting candidates for a job or product selection. When multiple criterion are available the decision making task becomes even more tedious. Scientific methods are necessary to arrive at an appropriate decision based on the available criterion.

TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is an efficient method to arrive at an apt decision scientifically. TOPSIS chooses the alternative of shortest the Euclidean distance from the ideal solution and greatest distance from the negative ideal solution after making a pairwise comparison between all the alternatives in the problem.

LITERATURE REVIEW

Robbi Rahim,S Supiyandi, et al applied the TOPSIS method for selection of employees in an organization.They used the following criterion in the selection of the best employees- job responsibilities, work discipline, work quality, and behavior.

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Hsu-Shih ShihHuan-Jyh ShyurE. Stanley Lee,et.al., gave an extension of TOPSIS for group decision making by providing options for the operations, such as normalization, distance measures and mean operators.

Hanine, M., Boutkhoum, O., Tiknioune, A. *et al.* analyzed the structure of the ETL software selection problem and obtained weights of the selected criteria.

Surendra Singh Gautam,Abhishekh,S. R. Singh applied TOPSIS for Multi Criteria Decision in Fuzzy Environment,

Five crops Tomato, Chilli, Cabbage, Bhendi and Brinjal are considered for this study.

The most common type of tomatoes are globe.

a) i) Tomato: Tomato is a warm season crop.

Table 1. Conditions for Tomato irrigation

Ideal temp	Rainfall	Not advisable
21-24°C.	Low to medium	Frost and high humidity

MATERIALS AND METHODS.

ii) **Table 2.** Some varieties of tomatoes

	Released by IARI	Released by IIHR	Released by PAU	Released by GBPUAT, Pantnagar
1	Pusa Rohini,	Arka Vikas	Pb. Kesari,	Pant T-10
2	Pusa Sadabahar	Arka Saurabh	Punjab Chhuhara,	AC-238,
3	Pusa Hybrid 8.4 2	Arka Meghali,	S-12,	Pant T-3
4	Pusa Hybrid	Arka Shreshta	Sel-152,	
5	Sioux	Arka Abhijit	PAU-2372 ,	

b) Some popular varieties of chillies grown and exported from India.

Table 3 Popular varieties of chillies grown and exported from India.

	North-East Region	Kashmir. ...	Andhra Pradesh.	Gujarat.	Kerala. ...	Tamil Nadu	Karnataka.	Manipur.
	Bhut Jolokia,	Kashmiri Chillies,	Guntur Chilli,	Jwala Chilli,	Kanthari Chilli,	Ramnad Mundu/ Gundu	Byadagi Chilli,	Dhani

c) Cabbage:

Table 3 Popular varieties of chillies

 Popular varieties of Cabbage				
Golden Acre	Pusa Mukta	Pusa Drumhead	K-1	Kaveri
Bajrang	Pusa Synthetic	Pride of India	Ganga	Hariana

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d) Bhendi

Table 4 Popular varieties of Bhendi

	Pusa Sawani	MDU1	Haritha	Janardhan
	Developed atIARI. New Delhi.	Agricultural College and Research Institute, Madurai, TNAU, by gamma irradiation of the seeds of Pusa Sawani.	ANGRAU	ANGRAU.

e) Brinjal:

Table 5 Popular varieties of Bhendi

 Popular varieties of Brinjal:				
Pusa Krishna (DBR-03): This variety is popular for commercial cultivation	Pusa Kranti	Hybrid: PHBL-51	Hybrid: PBHL-52,DBPR-23 (Pusa Vaibhav),	DBPR-23 (Pusa Vaibhav),

METHODOLOGY

The appropriate weights for the attributes are calculated. Saaty scale is implemented.

[1] For this a pairwise comparison matrix is constructed for the criterion and normalized.
[2] From this matrix the weights are calculated as average of the values for each criterion.
[3] The weighted sums are calculated.
[4] The weighted sum divided by weights is lambda (λ).
[5] The average value of lambda for all the criteria is denoted as average lambda (Avg.λ) or lambda max.

The consistency index is **CI = (**Lambda MAX-n)/(n-1) is calculated.

Next the consistency ratio, CR is calculated as CI/RI where RI is the random index (in this case 4 criterion implies n =4 for which RI is .9) from table 5. If CR is less than 0,10, accept the weights else the weights have to be reviewed.

Algorithm for crop selection

Consistency Index CI = (Lambda MAX-n)/(n-1) [1]

Consistency Ratio = Consistency Index /Random Index CI/RI [2]

TOPSIS METHOD FOR MCDM

Step 1 Find the Normalized Matrix

$$\bar{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}^{2}}} \quad [3]$$

Step 2 Find the weighted normalized matrix

$$V_{ij} = \bar{X}_{ij} * W_j \quad [4]$$

Step 3

Calculate the ideal best and ideal worst values V_j^+ and V_j^- [Maximum and minimum values]

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Step 4 Calculate the Euclidean distance from the ideal best and ideal worst.

$$S_i^+ = \sqrt{\sum_{j=1}^{m}\left(V_{ij} - V_j^+\right)^2} \qquad [5]$$

$$S_i^- = \sqrt{\sum_{j=1}^{m}\left(V_{ij} - V_j^-\right)^2} \qquad [6]$$

Step 5 Calculate the performance score or ranks

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-} \qquad [7]$$

Flow chart 1 criterion weight calculation

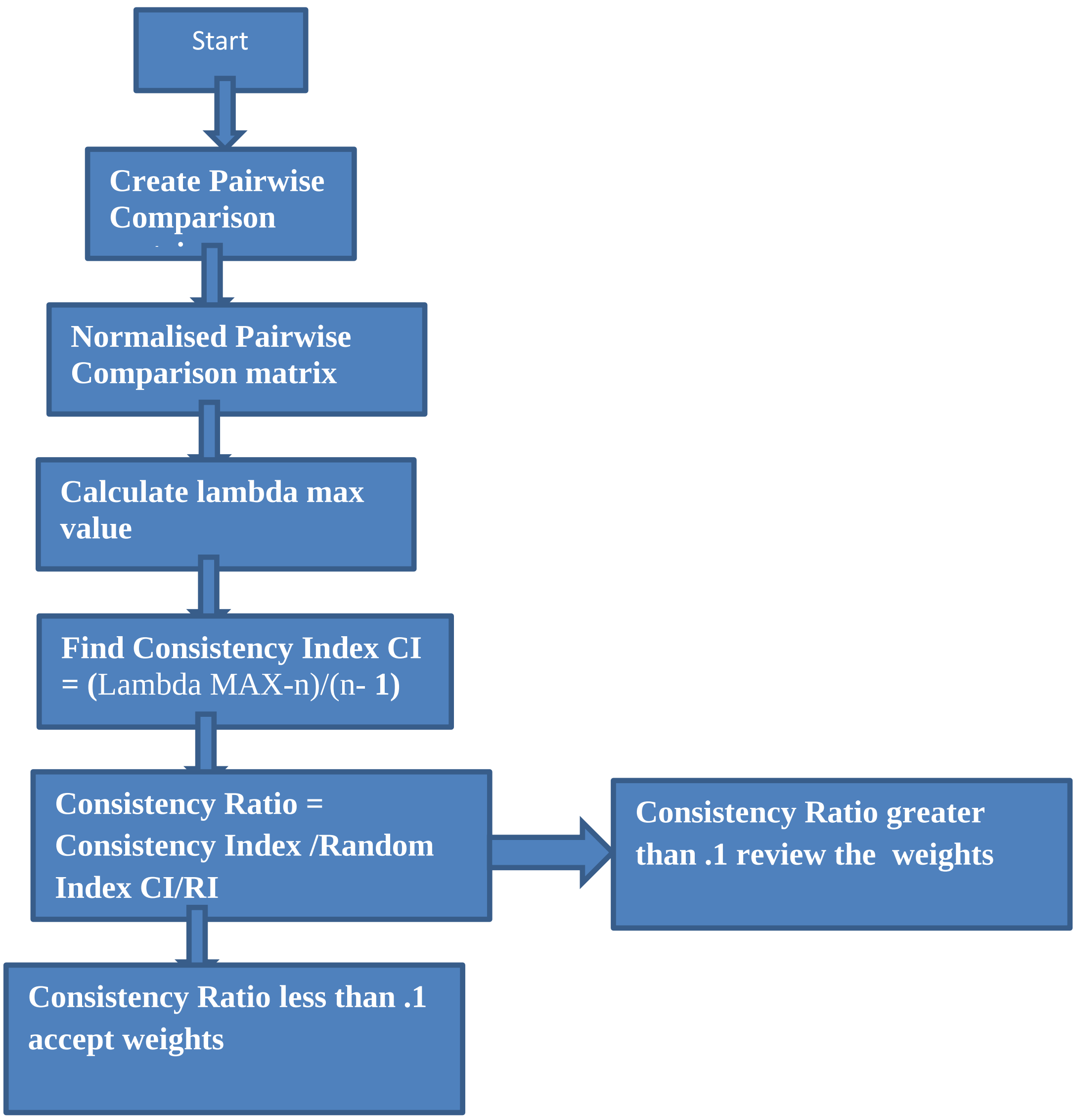

Figure 1. Criterion weight calculation

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Table 6 Data pertaining to the selected crops

	Cost of cultivation	**Yield (MT/ha)**	**Net income (Rs.) (at the lowest price)**	**Market price (Rs.) Lowest**
Tomato	61000	50	19500	2
Chilli	46000	22	12800	5
Cabbage	49000	75	57833	3
Bhendi	49000	10	32333	6
Brinjal	50000	60	35000	2
Sum of squares	13139000000.00	12309.00	6159168778.00	78.00
Square roots	114625.48	110.95	78480.37	8.83

Table 6 gives the criterion pertaining to the crops selected for analysis. The factors include cultivation costs/ha, yield ,net income and market price.

NORMALISED DECISION MATRIX

Table 7 Normalized decision matrix

	Cost of cultivation	**Yield (MT/ha)**	**Net income (Rs.) (at the lowest price)**	**Market price (Rs.) Lowest**
Tomato	0.53	0.45	0.25	0.23
Chilli	0.40	0.20	0.16	0.57
Cabbage	0.43	0.68	0.74	0.34
Bhendi	0.43	0.09	0.41	0.68
Brinjal	0.44	0.54	0.45	0.23
Sum of squares	1.00	1.00	1.00	1.00

PAIRWISE DECISION MATRIX

Table 8 Pairwise decision matrix

	Cost	**Yield (MT/ha)**	**Net income (Rs.) (at the lowest price)**	**Market price Minimum (Rs.)**
Cost	1.00	0.33	0.20	2.00
Yield (MT/ha)	3.00	1.00	0.33	4.00
Net income (Rs.) (at the lowest price)	5.00	3.00	1.00	4.00
Market price Minimum (Rs.)	0.50	0.25	0.25	1.00
	9.50	4.58	1.78	11.00

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DECISION MATRIX WITH NORMALIZED WEIGHTS

Table 8 Decision matrix

	Cost	**Yield (MT/ha)**	**Net income (Rs.) (at the lowest price)**	**Market price Minimum (Rs.)**	**Weights**
Cost	0.11	0.07	0.11	0.18	0.12
Yield (MT/ha)	0.32	0.22	0.19	0.36	0.27
Net income (Rs.) (at the lowest price)	0.53	0.65	0.56	0.36	0.53
Market price Minimum (Rs.)	0.05	0.05	0.14	0.09	0.08
	1.00	1.00	1.00	1.00	1.00

Table 9 Decision matrix with normalized weights

	Cost	**Yield (MT/ha)**	**Net income (Rs.) (at the lowest price)**	**Market price Minimum (Rs.)**	**Wt. Sum**
Weight	**0.12**	**0.27**	**0.53**	**0.08**	
Cost	1.00	0.33	0.20	2.00	0.48
Yield (MT/ha)	3.00	1.00	0.33	4.00	1.14
Net income (Rs.) (at the lowest price)	5.00	3.00	1.00	4.00	2.27
Market price Minimum (Rs.)	0.50	0.25	0.25	1.00	0.34

Table 10 Decision matrix with Lambda Max

	Cost	**Yield (MT/ha)**	**Net income (Rs.) (at the lowest price)**	**Market price Minimum (Rs.)**	**WT SUM**	**WTS**	**LAMBDA**	**LAM MAX**
Weight	0.12	0.27	0.53	0.08				
Cost	1.000	0.333	0.200	2.000	0.483	0.118	4.092	
Yield (MT/ha)	3.000	1.000	0.333	4.000	1.139	0.271	4.200	
Net income (Rs.) (at the lowest price)	5.000	3.000	1.000	4.000	2.268	0.526	4.309	

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Market price Minimum (Rs.)	0.500	0.250	0.250	1.000	0.343	0.085	4.055	4.164

Consistency Index CI = (Lambda MAX-n)/(n-1) =(4.164 - 4)/3=0.05.

Consistency Ratio = Consistency Index /Random Index CI/RI= .05/0.9=.06

CR value is less than 0.1 hence weights are acceptable.

The ideal worst and best are denoted as V^-- and V+ respectively. The Eucledian distance for ideal best Si+ and ideal worst Si- are calculated using formulae [5] and [6]. The performance index Pi is calculated from [7] and the values of the performance index are ranked in increasing order. The results are tabulated in table 10 below.

Table 11 Rank matrix

Crop	Cost of cultivation	Yield (MT/ha)	Net income (Rs.) (at the lowest price)	Market price (Rs.) Lowest	Si+	Si-	Pi	Rank
Tomato	0.190	0.113	0.062	0.034	0.164	0.093	0.362	4
Chilli	0.143	0.050	0.041	0.085	0.188	0.074	0.283	5
Cabbage	0.160	0.169	0.184	0.051	0.061	0.208	0.772	1
Bhendi	0.126	0.023	0.103	0.102	0.167	0.112	0.401	2
Brinjal	0.156	0.135	0.111	0.034	0.109	0.137	0.557	3
V+	0.126404	0.169001	0.184228	0.101905				
V-	0.189918	0.022533	0.040775	0.033968				

Benefits of the Study

The methodologies and insights offered by this study are essential for equipping farmers with the tools and knowledge needed to navigate the complexities of modern agriculture effectively. By empowering farmers with systematic decision-making approaches grounded in sound principles and data driven analysis, this study has the potential to yield tangible benefits in terms of improved productivity, profitability, and sustainability across agricultural landscapes. Farmers benefit from the methodologies and insights provided in this study for several reasons.

1. Enhanced Decision-making: Farmers often face numerous challenges when selecting crops, including market uncertainties, changing environmental conditions, and resource constraints. The systematic approach offered by the TOPSIS-AHP methodology empowers farmers to make more informed decisions based on a comprehensive evaluation of multiple criteria. This can help mitigate risks and optimize outcomes, leading to improved farm productivity and profitability.

2. Scientific Rigor: Traditional methods of crop selection may rely heavily on intuition and anecdotal evidence, which can be subjective and prone to biases. By integrating rigorous analytical techniques such as TOPSIS and AHP, this study brings a higher level of scientific rigor to the decision-making process. Farmers can rely on data-driven insights and methodologies grounded in established principles, enhancing the credibility and reliability of their decisions.

3. Adaptation to Changing Conditions: Agriculture is inherently dynamic, with factors such as climate change, market trends, and regulatory policies constantly evolving. The flexible nature of the TOPSIS-AHP methodology allows farmers to adapt their crop selection strategies in response to changing conditions. By considering diverse criteria and weighing them appropriately, farmers can better anticipate and respond to emerging challenges and opportunities in the agricultural landscape.

4. Sustainability and Resilience: Sustainable agriculture is increasingly recognized as essential for long-term food security and environmental stewardship. By

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prioritizing criteria such as environmental impact and resource efficiency within the TOPSIS-AHP framework, farmers can align their crop selection practices with sustainability goals. This not only enhances the resilience of individual farms but also contributes to broader efforts to build sustainable food systems.

Conclusion

The application of the TOPSIS-AHP methodology for informed crop selection among farmers presents a significant advancement in agricultural decision-making. Through the integration of TOPSIS and AHP techniques, multiple crops are effectively assessed based on diverse criteria such as cost of cultivation, yield, net income, and market price. The calculation of weights using the Saaty method ensured consistency in decision model, providing farmers with reliable insights into crop selection. The analysis revealed cabbage as the top-performing crop, as indicated by its maximum performance score of 0.772. This outcome underscores the efficacy of the TOPSIS-AHP approach in identifying crops that align with farmers objectives of maximizing profitability and productivity while considering various constraints and trade-offs.

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