PLANT SCIENCE TODAY
Vol 13(sp1): 1-8
https://doi.org/10.14719/pst.8988

eISSN 2348-1900

RESEARCH ARTICLE

Selection of best conservation tillage alternative for *Kharif* rice using AHP and TOPSIS methods

Tufleuddin Biswas[1,2*], Anurup Majumder[2], Anjana Baitalik[3], Mujahida Sayyed[4], Promil Kapoor[5], Shamik Dey[6], Idemakanti Chandrakanth Reddy[7], Perumalla Srikanth[8], Puja Singh[9], Swarnali Duary[10], Shivangi Singh[1], Shravani Daware[1], Bhanothu Shiva[11], Sunil Kumar Pandey[12], Soumik Ray[7] & Pradeep Mishra[13]

[1]Symbiosis Statistical Institute, Symbiosis International (Deemed University), Pune 411 004, Maharashtra, India
[2]Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741 252, West Bengal, India
[3]Department of Anatomy, College of Medicine and JNM Hospital, The West Bengal University of Health Sciences, Kalyani 741 235, Nadia, West Bengal, India
[4]Department of Mathematics and Statistics, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Ganj Basoda, Vidisha 464 221, Madhya Pradesh, India
[5]Department of Plant Pathology, Chaudhary Charan Singh Haryana Agricultural University, Hisar 125 004, Haryana, India
[6]Faculty of Agriculture, JIS University, Agarpara 700 109, West Bengal, India
[7]M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Gajapati 761 211, Odisha, India
[8]Department of Agricultural Microbiology, School of Agriculture, Mohan Babu University, Tirupati 517 102, Andhra Pradesh, India
[9]Department of Soil Science and Agricultural Chemistry, Horticulture College, Khuntpani, Chaibasa, BAU, Ranchi 833 201, Jharkhand, India
[10]Department of Agriculture, Brainware University, Kolkata 700 125, West Bengal, India
[11]Department of Plant Pathology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741 252, West Bengal, India
[12]Department of Plant Physiology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, College of Agriculture, Powarkeda, Narmadapuram 461 110, Madhya Pradesh, India
[13]College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Rewa 486 001, Madhya Pradesh, India

*Correspondence email - tufleuddinbiswas@gmail.com

Received: 20 April 2025; Accepted: 06 November 2025; Available online: Version 1.0: 05 March 2026

Cite this article: Tufleuddin B, Anurup M, Anjana B, Mujahida S, Promil K, Shamik D, Idemakanti CR, Perumalla S, Puja S, Swarnali D, Shivangi S, Shravani D, Bhanothu S, Sunil KP, Soumik R, Pradeep M. Selection of best conservation tillage alternative for *Kharif* rice using AHP and TOPSIS methods. Plant Science Today. 2026; 13(sp1): 1-8. https://doi.org/10.14719/pst.8988

Abstract

Conservation agriculture (CA) stands out as a recognized alternative to conventional tillage methods, aiming to conserve natural resources while delivering various farm benefits. A field experiment on *Kharif* rice was conducted during 2019–2020 at the BCKV Farm, Balindi, West Bengal. By integrating different tillage techniques, such as zero, reduced and traditional methods, along with considerations for crop residue quantity and fertilization. CA practices were constructed to minimize energy expenditure for crop cultivation. The performance of these practices was evaluated using diverse indicators encompassing energy usage, benefit-cost ratio, soil criteria, crop criteria (Agronomic) and plant protection criteria. Three multi-criteria decision-making methods (MCDM), namely (i) Analytic Hierarchy Process (AHP), (ii) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and (iii) Weighted Sum Model (WSM) were applied to identify and validate the most suitable tillage approach for *Kharif* rice. TOPSIS ranked reduced tillage as the top choice for *Kharif* rice cultivation, followed by conventional tillage. The same was validated by WSM by deriving the similar ranking. This underscores the potential for promoting and adopting reduced tillage as a viable alternative. AHP played a crucial role in establishing the relative importance of various criteria, ensuring the reliability of decision-making processes. By pinpointing areas for improvement, particularly in addressing weak links, the integration of AHP and TOPSIS facilitated decision-makers in discerning the effects of different criteria on *Kharif* rice under various CA regimes. This approach provides valuable insights for optimizing agricultural practices and enhancing overall performance. It will assist stakeholders in making cost-effective decisions to improve crop productivity and promote eco-friendly farming practices.

Keywords: AHP; conservation-agriculture; *Kharif* rice; MCDM; TOPSIS; WSM

Introduction

Entrepreneurship and effective decision-making are paramount in agriculture across various stages, including field preparation, irrigation scheduling, fertilizer and pesticide/herbicide application and harvesting. Each stage demands precise and well-defined criteria for decision-making, with different factors holding varying degrees of importance in selecting the optimal course of action. However, numerous conflicting issues arise during the implementation of these activities, complicating the agriculture industry's decision-making process (1, 2). Thus, Multi-Criteria Decision-Making (MCDM) methods have become essential for facilitating complex decision-making processes involving multiple, often conflicting criteria (3). Within the framework of conservation agriculture, three core principles hold significant sway: minimizing soil disturbance, cultivating cover crops and implementing judicious crop rotation (4). These principles underscore the importance of reducing soil disruption, fostering cover crop growth and executing a carefully planned crop rotation schedule. By adhering to these principles, conservation agriculture aims to achieve environmental sustainability while garnering economic advantages. The focus is on preserving soil health, upholding ecological balance and sustainably and responsibly enhancing agricultural productivity.

Several MCDM techniques are well-documented in the literature. Among the widely recognized methods are the Simple Additive Weighting (SAW), Analytic Hierarchy Process (AHP), VlseKriterijumsko Optimiranje I Kompromisno Resenje (VIKOR), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Elimination and Choice Expressing Reality (ELECTRE) and the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) (5–7). However, they are all intended to handle particular scenarios involving decision-making. Each of these methods has pros and cons. MCDM is rarely used in agricultural trials to select the optimal option among various options (varieties, fertilizer doses, etc.). Several studies employed the TOPSIS method in selecting the best treatment alternative in agricultural experiments (8–10). Documents regarding the hybrid applications of MCDM methods, specifically AHP and TOPSIS, have been used in many previous agriculture investigations (11, 12).

The application of MCDM methods in rice crops has been reported in the literature (13–18). However, all previous investigations were mainly performed to assess land or site suitability. AHP and TOPSIS were employed to select the best management practices under the rice-wheat cropping system (3). A similar study was also conducted using fuzzy TOPSIS to evaluate crop patterns (19).

The present research used a hybrid method (TOPSIS and AHP) to select the best tillage among a regime of tillage (conventional, reduced and zero tillage) for *Kharif* rice. And the results of TOPSIS are validated by WSM. The results of the study emphasize the overall farm advantages and the environmental sustainability of preserving soil health. This research will benefit Indian farming practices specifically and global farming practices generally. By providing stakeholders with data-driven insights, this strategy enables cost-effective decision-making aimed at boosting crop yields and fostering environmentally sustainable crop production methods. In addition, state policymakers can formulate robust, state-specific eco-friendly agriculture policies to enhance their contribution to the gross domestic product and self-sufficiency.

Materials and Methods

Field experimentation, treatments (alternatives) and criteria selection

This study was undertaken at the Balindi Research Complex of Bidhan Chandra Krishi Viswavidyalaya (BCKV) research area in West Bengal during the *Kharif* season, focusing on rice cultivation in 2018–2019. The field, which covered an area of approximately 2.0 hectare per cropping system, was segmented into three sections based on the intensity of tillage, determined by the energy consumed. The plots were designated reduced, conventional tillage and zero tillage to reflect different practices. The conventional tillage plot was initially prepared using a tractor-drawn disc plough for primary tillage. After the primary tillage, the field underwent secondary tillage consisting of two passes with a rigid-tyne cultivator and a rotary tiller. The aim was to achieve a well-tilled and uniform seedbed. On the other hand, the reduced tillage plot underwent sequential tillage operations using a wide-tyne cultivator and an offset disc harrow was utilized as part of the secondary tillage process to enhance soil preparation. Within the framework of zero tillage, characterized by minimal soil disturbance, sowing was carried out using a zero-till seed-cum-fertilizer drill.

We considered three tillage alternatives in the present investigation: reduced, conventional and zero tillage. These alternatives were appraised based on various conflicting decision-making criteria. Agronomic criteria, primarily grain yield, were assessed to understand the impact of each tillage method on crop productivity. Soil health-related criteria such as soil organic carbon, nitrogen, phosphorus, potassium, zinc, sulphur, microbial biomass carbon, porosity, bulk density and water-holding capacity were analyzed to gauge the effects of tillage practices on soil health and fertility. Plant protection criteria, including white ear head per square meter, percentage of tiller infested per hill and damage to leaves per square meter, were examined to assess the level of pest and disease pressure under each tillage system. Energy consumption, measured in megajoules per hectare (MJ/ha), was divided into categories, including human energy, chemical energy, electricity, fertilizer, residues, machinery, irrigation and fuel, to evaluate the energy inputs associated with each tillage method. Economic viability was determined by calculating the benefit–cost (B:C) ratio to understand the financial implications of adopting different tillage practices.

TOPSIS procedure

Consider a scenario with T alternatives, denoted as $S_1, S_2, \ldots, S_T$ and N criteria to calculate each alternative S_t, denoted as $P_1, P_2, \ldots, P_N$ (as illustrated in Table 1). The value of the t-th alternative on the nth criterion is represented as $Y_{t\times n}$. This signifies the measurement associated with the t-th alternative and the nth criterion. It is important to note that $S_t = (y_{t1}, y_{t2}, \ldots y_{tN})$ and $P_n = (y_{1n}, y_{2n}, \ldots y_{nk} \ldots y_{tn})$; here, t ranges from 1 to T, representing the alternatives and n ranges from 1 to N, representing the criteria. These values enable methodical calculation and association of each alternative across all criteria.

Construction of primary database structure

TOPSIS (20) involves utilizing an early database structure. Table 1 is structured with alternatives (treatments) organized in rows and criteria (criteria) arranged in columns.

The given number y_{tn} and their corresponding matrix will be

$$(\boldsymbol{Y}_{tn})_{T\times N} = \begin{bmatrix} y_{11} & \cdots & y_{1N} \\ \vdots & y_{tn} & \vdots \\ y_{T1} & \cdots & y_{TN} \end{bmatrix}$$

Step 1. In the first step, the nth criteria vector, P_n, is calculated. This vector is normalized, resulting in $\acute{P}_n$, where $\acute{P}_n$ represents the normalized criteria vector.

Table 1. Decision matrix formation for TOPSIS analysis

Criteria/Treatments	P_1	P_2	…	P_n	…	P_N
S_1	y_{11}	y_{12}	…	y_{1n}	…	y_{1N}
S_2	y_{21}	y_{22}	…	y_{2n}	…	y_{2N}
…	…	…	…		…	…
S_t	y_{t1}	y_{t2}	…	y_{tn}	…	y_{tN}
…	…	…	…		…	…
S_T	y_{T1}	y_{T2}	…	y_{Tn}	…	y_{TN}

$$\acute{P}_n = \frac{P_n}{|P_n|} = (y_{1n}/|P_n|, y_{2n}/|P_n| \dots y_{tn}/|P_n|) \quad (1)$$

Where $|P_n| = \sqrt{\sum_{t=1}^{T}(y_{tn})^2}$ is the Euclidean distance of P_n is calculated to ensure that the newly formed criteria vectors are of equal length. This normalization process makes the criteria vectors unit-free and enables direct comparisons.

Step 2. Calculation of weights: The weight of the criteria vector (W_n) was calculated using the AHP method of pairwise comparison (Table 2) to construct the normalized decision matrix (V_{kn}).

$$W_n = (w_1, w_2, \dots, w_n)¢ \text{ and } \sum_{n=1}^{N} W_n = 1 \quad (2)$$

Step 3. The columns of the normalized decision matrix are scaled by their respective weights, W_n, obtained from Eq. (3). This process results in a weighted and normalized decision matrix where each element represents the product of the normalized value and the associated weight.

$$V_{kn} = \acute{P}_n W_n \quad (3)$$

Step 4. This step involves determining PIS and NIS: The positive ideal solution (PIS) is derived by choosing the optimal value for each attribute from the weighted decision matrix (3). In contrast, the negative ideal solution (NIS) is established by selecting the least favourable value for each attribute from the weighted decision matrix, as shown in Eq. (5).

$$S^+ = (S_1^+, S_2^+, \dots S_T^+) \quad (4)$$

$$S^- = (S_1^-, S_2^-, \dots S_T^-) \quad (5)$$

Now the ideal value and negative ideal value are determined by

S_T^+ = {Max V_{tn} the benefit criteria or Min of V_{tn} the cost criteria}

S_T^- = {Max V_{tn} the cost criteria or Min of V_{tn} the benefit criteria}

Step 5. Computation of distance of viable solution from

PIS, $$D_t^+ = \sqrt{\sum_{n=1}^{N}(V_{tn} - S_t^+)^2} \quad (6)$$

NIS, $$D_t^- = \sqrt{\sum_{n=1}^{N}(V_{tn} - S_t^-)^2} \quad (7)$$

Step 6. Estimation of relative degree of score

It can be found in the following equation

$$R_t = \frac{D_t^-}{(D_t^+ + D_t^-)} \quad (0 \le R_t \le 1; t = 1,2,\dots.T) \quad (8)$$

Hence, when the values of R_t are higher, it signifies a more advantageous ranking for the alternative. Higher values indicate that the alternative demonstrates a larger distance from the negative ideal solution and closer proximity to the positive ideal solution.

Criteria weight computation using AHP

Saaty (21) proposed the analytic hierarchy process, which is based on measurement theory and uses pairwise comparisons. It relies on expert decisions to create priority scales for assessing criteria (21).

Steps in the AHP process

The steps in AHP process: (i) Model development, (ii) criteria weight derivation, (iii) checking consistency and (iv) determine the overall (global) priorities and make the final decision. A pairwise comparison matrix is used to evaluate the relative importance weights of a set of n criteria using pairwise comparisons (Table 2). This matrix is constructed as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots a_{1j} \dots & a_{1n} \\ a_{21} & a_{22} & \dots a_{2i} \dots & a_{2n} \\ \dots & \dots & \dots \dots & \dots \\ a_{i1} & a_{i2} & \dots a_{ij} \dots & a_{in} \\ a_{1n} & a_{2n} & \dots a_{in} \dots & a_{nn} \end{bmatrix}, a_{ii} = 1, a_{ij} = \frac{1}{a_{ji}}, a_{ji} \neq 0$$

; Where, i = 1, 2 …m and j = 1, 2 …n;

If the number of comparisons, calculated by $n(n-1)/2$, matches the number of criteria, denoted as n, then the elements {a_{ij}} will satisfy the conditions $w_i/w_j = 1/a_{ji}$ and $a_{ii} = 1$, where i ranges from 1 to m and j ranges from 1 to n. {a_{ij}} indicates the preference level of the ith criteria over the jth criteria. The criteria are denoted by a_1, a_2, … a_n. The comparative weights are obtained by determining the eigenvector (w) associated with the maximum eigenvalue (T_{max}) that satisfies the equation $Aw = T_{max}W$, where A is the matrix. The value of T_{max} should be equal to or greater than n, where n

Table 2. Saaty's pairwise comparison (21)

Intensity of importance	Description
1: Equally importance	Both activities contribute equally to the objective
2: Slight importance	
3: Moderate importance	One activity is slightly preferred or given a slight advantage based on expertise and judgment
4: Moderate plus importance	
5: Strong importance	One activity is significantly favored over the other based on knowledge and decision-making
6: Strong plus	
7: Very strong importance	One activity clearly dominates the other, as demonstrated in practical implementation
8: Very, very strong importance	
9: Extreme importance	The highest level of evidence supports the preference for one activity over the other
Reciprocals of the above	If activity *i* is compared to activity *j*, then activity *j* is assigned the reciprocal value compared to activity *i*
1.1–1.9: Close proximity	Differences are subtle and difficult to discern, but these small variations still indicate relative importance

denotes the dimensionality of matrix A. The disparity between T_{max} and n indicates the presence of inconsistency in the judgments. If T_{max} is equal to n, it signifies that the judgments are consistent. To quantify the consistency, a Consistency Index (CI) is calculated using the

$$\text{Consistency Index (CI)} = \frac{(\tau_{max} - n)}{(n-1)}$$

To evaluate the level of consistency, the calculated CI needs to be compared with the Consistency Indices of randomly generated matrices. Saaty conducted a comprehensive analysis by generating many random matrices of increasing order and determining their CIs. The Consistency Ratio (CR) is then derived by dividing the calculated CI by the corresponding index from the random matrix (21). This allows for a comparison between the consistency of the actual judgments and the expected consistency based on random judgments. Saaty further proposed that if the CR surpasses 0.1, the judgments may be too inconsistent to be considered reliable. A CR value slightly above 0.1 is typically acceptable, while a 0 CR value signifies a perfectly consistent judgment. The CR serves as a measure to assess the level of inconsistency in random judgments and guides the reliability of the judgments made.

WSM procedure

WSM, also known as simple additive weighting (SAW), is a well-known and easy MCDM approach for ranking treatments, given a number of decision criteria (22). For our experiment $\Sigma_{n=1}^{N} w_n y_{tn}$ with T alternatives (S_1, S_2, ... , S_T) and N criteria to calculate each alternative S_t, denoted as P_1, P_2, ... , P_N. Then, the total (i.e., when all the criteria are considered simultaneously) importance of alternative S_t, denoted as $S_t^{WSM\ Score}$, is referred to as , where y_{tn} is the performance value of alternative S_t when it is evaluated in terms of criterion P_n. Higher $S_t^{WSM\ Score}$ value indicates better performance.

Software application

In order to analyze the data on different criteria and sub-criteria of the three alternatives using AHP, TOPSIS and WSM, we employed Microsoft Excel (Version 2013, Microsoft, 2013). Similarly, the AHP tree was drawn in Fig. 1 using the Python programming language (Version 3.12) with the 'Matplotlib' package (https://matplotlib.org/).

Results and Discussion

Weights for all main and sub-criteria are determined using the AHP

Pairwise comparisons are conducted for all five main criteria: soil, agronomy, energy input, crop protection and economics (B:C) using the scores given by the experts of different disciplines following the Saaty score's chart for assigning weights. Also, the same was calculated for the corresponding sub-criteria. After comparison, all the decision matrices were constructed (Tables 3

Table 3. Weight calculation of all five main criteria from the decision matrix

Main criteria	1	2	2	4	5
1	1.00	3.00	2.00	6.00	5.00
2	0.33	1.00	2.00	5.00	4.00
3	0.50	0.50	1.00	5.00	6.00
4	0.17	0.20	0.20	1.00	1.00
5	0.20	0.25	0.18	1.00	1.00
Weight	0.421	0.252	0.222	0.051	0.054

CR = 5.2 %, Main Eigen number = 5.232.

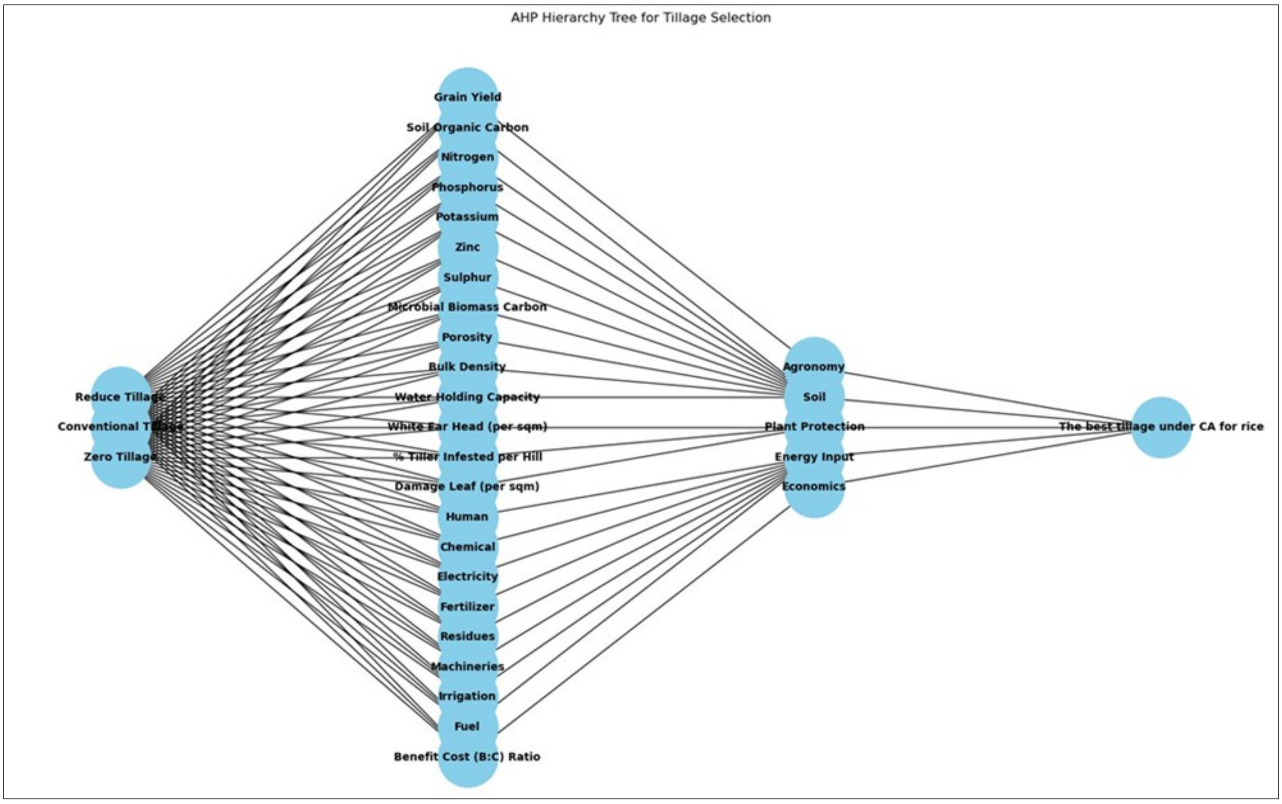

Fig. 1. Structure of AHP tree, presenting different treatment alternatives, main and sub-criteria with the goals (Python 3.12).

Table 4. Weight calculation of crop protection sub-criteria

Subcriteria	WEH (sq m^{-1})	%TI (hill^{-1})	DL (sq m^{-1})
WEH (sq m^{-1})	1.00	4.00	5.00
%TI (hill^{-1})	0.25	1.00	3.00
DL (sq m^{-1})	0.20	0.33	1.00
Weight	0.674	0.226	0.101

CR = 9.0 %, Main Eigen number = 3.086.

Table 5. Weight calculation of soil sub-criteria

Subcriteria	1	2	3	4	5	6	7	8	9	10
1	1.00	4.00	7.00	8.00	8.00	6.00	4.00	7.00	4.00	4.00
2	0.25	1.00	4.00	7.00	6.00	4.00	3.00	7.00	2.00	2.00
3	0.14	0.25	1.00	4.00	3.00	2.00	1.00	6.00	0.33	0.50
4	0.12	0.14	0.25	1.00	1.00	0.50	0.33	1.00	0.33	0.33
5	0.13	0.17	0.33	1.00	1.00	0.33	0.50	1.00	0.33	0.25
6	0.17	0.25	0.50	2.00	3.00	1.00	2.00	3.00	0.33	0.33
7	0.25	0.33	1.00	3.00	2.00	0.50	1.00	2.00	0.50	1.00
8	0.14	0.14	0.167	1.00	1.00	0.33	0.50	1.00	0.50	1.00
9	0.25	0.50	3.00	3.00	3.00	3.00	2.00	2.00	1.00	1.00
10	0.25	0.50	2.00	3.00	4.00	3.00	1.00	1.00	1.00	1.00
Weight	0.338	0.183	0.076	0.027	0.027	0.058	0.061	0.034	0.104	0.091

CR = 5.9 %, Main Eigen value = 10.23.

Criteria – 1: Soil organic carbon; 2: Nitrogen; 3: Phosphorus; 4: Potassium; 5: Zink; 6: Sulphur; 7: Microbial biomass carbon; 8: Porosity; 9: Bulk density; 10: Water holding capacity.

Table 6. Weight calculation of energy criteria

Energy criteria	1	2	3	4	5	6	7	8
1	1.00	0.50	3.00	2.00	0.33	0.17	0.25	0.17
2	2.00	1.00	4.00	3.00	2.00	0.50	0.33	0.20
3	0.33	0.25	1.00	0.50	0.20	0.13	0.33	0.13
4	0.50	0.33	2.00	1.00	0.25	0.14	0.20	0.14
5	3.00	0.50	5.00	4.00	1.00	0.25	0.50	0.33
6	6.00	2.00	8.00	7.00	4.00	1.00	3.00	2.00
7	4.00	3.00	3.00	5.00	2.00	0.33	1.00	2.00
8	6.00	5.00	8.00	7.00	3.00	0.50	0.50	1.00
Weight (W_n)	0.046	0.096	0.026	0.032	0.090	0.298	0.188	0.223

CR = 6.50 %, principal eigenvalue = 8.60.

Criteria – 1: Human; 2: Chemical; 3: Electricity; 4: Fertilizer; 5: Residues; 6: Machineries 7: Irrigation; 8: Fuel.

–6) using AHP. Table 3 presents the main criteria' weights using the decision matrix. The maximum weight was calculated for the soil parameter (0.421), followed by agronomy (0.252), energy input (0.222), economics B:C (0.054) and plant protection (0.051). Table 4 indicates that the highest weight is 0.674 for white ear head (WEH) per square meter, followed by 0.226 for the percentage of tiller infestation (TI) per hill and 0.101 for damaged leaf (DL) per square meter. In Table 5, the soil sub-criteria showed the highest weight for soil organic carbon at 0.338, followed by nitrogen at 0.183, bulk density at 0.104, water holding capacity at 0.091, phosphorus at 0.076, microbial biomass carbon at 0.061, sulfur at 0.058, porosity at 0.034 and both potassium and zinc at 0.027. Table 6 indicates that machinery is assigned the highest weight (0.298), followed by fuel (0.223), irrigation (0.188), chemicals (0.096), residues (0.090), human labour (0.046), fertilizers (0.032) and electricity (0.026). After assigning weights to all 5 main criteria and their corresponding sub-criteria, Fig. 2 displays the normalized weights of all 23 sub-criteria under the banner of each main parameter. The CRs of the decision matrix for the main criteria and the sub-criteria were assessed with the corresponding eigenvalues. For each decision matrix, the derived CRs were less than 10 % (Tables 3–6), which signifies a consistent judgment while deriving the weights. Similarly, for each decision matrix, the obtained Eigenvalues were equal to the corresponding number of criteria, which also signifies a valid judgment of the requirements while assigning scores.

Ranking the tillage alternative using TOPSIS and WSM

From the TOPSIS analysis (Table 7, Fig. 3), the zero-tillage alternative showed the highest distance (0.199) from the ideal solution (PIS) and the lowest (0.144) from the NIS. In contrast, conventional tillage had a distance of 0.151 from the ideal solution and 0.177 from the NIS. The same ranking is also obtained using the WSM approach (Table 7), which validated the TOPSIS findings (Reduced (0.75) > conventional (0.59) > Zero (0.40)).

The TOPSIS rank, as depicted in Fig. 3, is based on the relative closeness value (R_t). The highest rank obtained using the R_t value is for reduced tillage (0.67), followed by conventional (0.54) and zero tillage (0.42). The good performance of reduced tillage may be attributed to single-pass and minimal soil disturbance operations, which lowered production costs and reduced land preparation time and irrigation needs, making

Table 7. TOPSIS ranking of 3 tillage systems

Alternative (tillage)	PIS (D_t^+)	NIS (D_t^-)	Relative closeness score (R_t)	TOPSIS rank	WSM scores	WSM rank
Conventional	0.151	0.177	0.54	2	0.59	2
Reduced	0.102	0.210	0.67	1	0.75	1
Zero	0.199	0.144	0.42	3	0.40	3

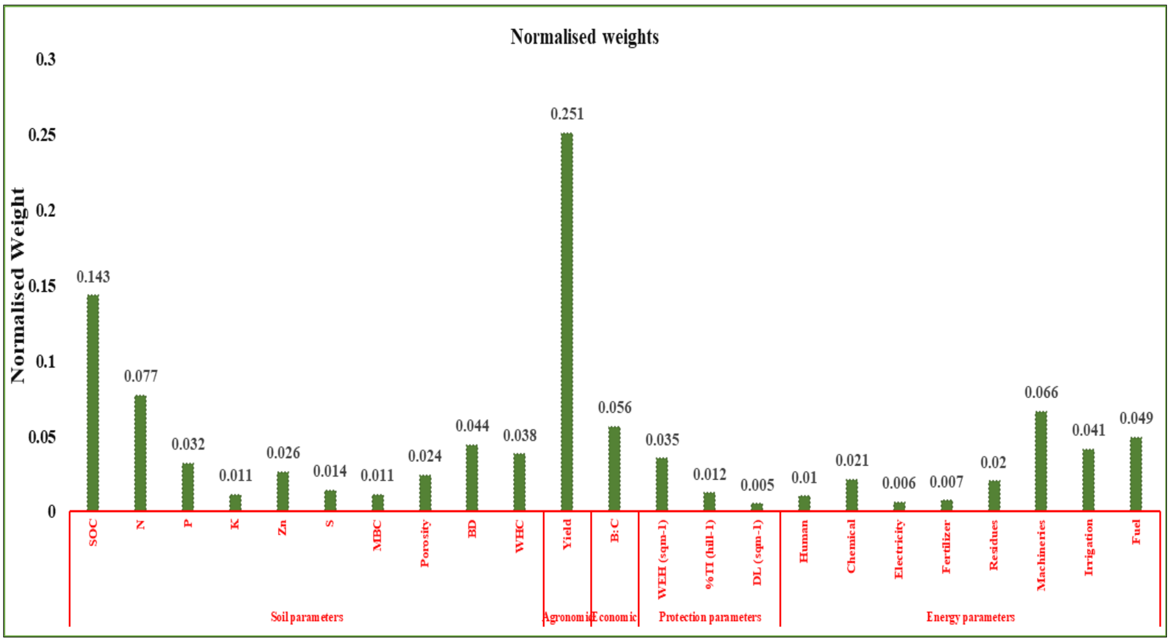

Fig. 2. Normalized weights (W_n).

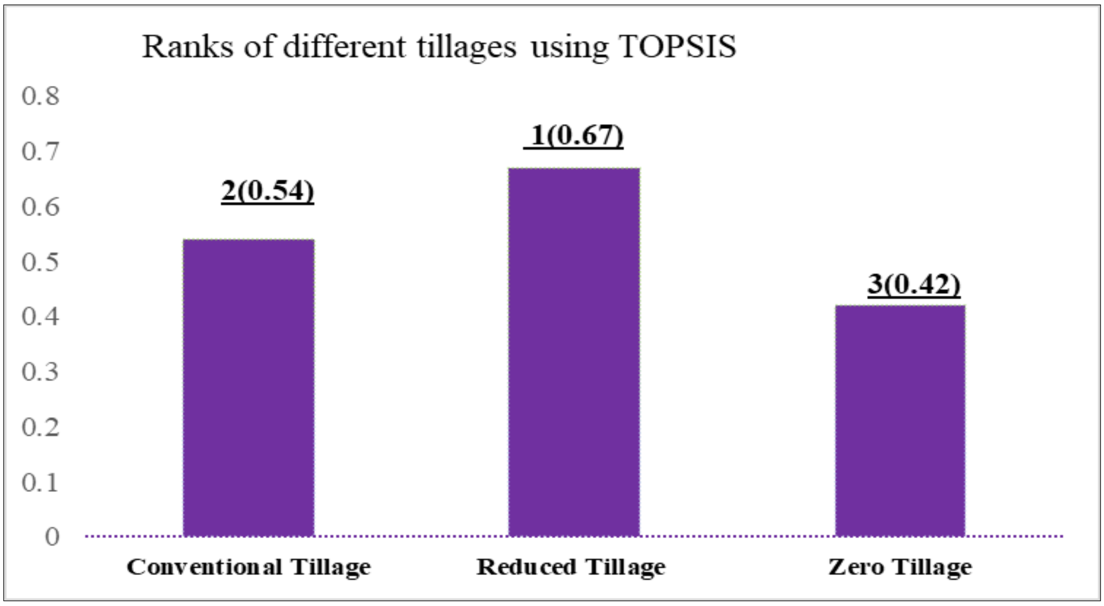

Fig. 3. Rank performance of tillage (relative scores).

unpuddled transplanting a viable method for establishing wetland rice in conservation agriculture systems (23). Analysis of energy data, including machinery, labour, fertilizers, fuel and irrigation, revealed that adopting conservative techniques (reduced tillage and zero tillage) for paddy rice cultivation significantly reduced production costs, working time by 47–61 %, mechanization costs by 42–58 % and fuel consumption by 48–63 %, leading to direct environmental benefits (24). The low performance of zero tillage may be due to a higher population of white ear heads (WEH) per square meter, a more significant percentage of tiller infestation (TI) per hill and more damaged leaves (DL) per square meter compared to conventional and reduced tillage. Reports are on the investigation of conservation agriculture (CA) practices for rice-based cropping systems (25). They found an abnormal increase in pest populations, particularly in zero tillage systems, such as armyworm (*Mythinma leucania*) (*Pseudaletia separata* (Wlk.)) in wheat and mealybug (*Brevennia rehi* (Lindinger)) and bandicoot rat (*Bandicota bengalensis* (Gray)) in rice. These results align with previous studies and findings. The hybrid (AHP-TOPSIS) method addressed the weak links and highlighted opportunities to enhance the performance of *Kharif* rice under various CA regimes, enabling decision-makers to analyze individual criteria and gain valuable insights for optimizing agricultural practices.

Conclusion

TOPSIS, in conjunction with AHP, assessed the alternatives (conventional, reduced and zero tillage) based on 23 criteria spanning five disciplines (soil, agronomy, plant protection, economics and energy use). The evaluation revealed that reduced tillage performed the best for *Kharif* rice, followed by conventional and zero tillage practices. The ranking results obtained from TOPSIS are also validated by WSM. AHP played a crucial role in establishing the relative importance of these criteria, ensuring the reliability of decision-making. By pinpointing areas for improvement, particularly in addressing weak links, the integrated approach of AHP and TOPSIS with WSM sheds light on opportunities to enhance the performance of *Kharif* rice under various CA regimes. This integration facilitated decision-makers in dissecting the effects of individual criteria, thereby offering valuable insights into optimizing agricultural practices. Thus, the combined employment of TOPSIS with AHP (validated by WSM) proves instrumental in significant decision-making processes, particularly when dealing with conflicting criteria across multiple fields.

Acknowledgements

The authors gratefully acknowledge Bidhan Chandra Krishi Viswavidyalaya, West Bengal, for providing the necessary facilities and support. We extend our sincere thanks to the Principal Investigator and all Co-PIs of the CAAST on CA Project for their guidance and contributions throughout the research.

Authors' contributions

TB contributed to conceptualization, methodology, formal analysis, software and original draft preparation. AM contributed to the methodology and overall supervision. AB, MS and PK reviewed and edited the manuscript. SD, ICR, PS[1], PS[2] and BS contributed to data curation. SD[1] data analysis and formatting the manuscript. SS performed data analysis and wrote the draft. SD[2] reviewed the manuscript. SKP, SR and PM reviewed the manuscript. All authors read and approved the final manuscript. [PS[1] stands for Perumalla Srikanth and PS[2] for Puja Singh; SD[1] stands for Swarnali Duary and SD[2] for Shravani Daware.]

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

References

1. Kumar A, Pant S. Analytical hierarchy process for sustainable agriculture: An overview. MethodsX. 2023;10:101954. https://doi.org/10.1016/j.mex.2022.101954
2. Rehman T, Romero C. The application of the MCDM paradigm to the management of agricultural systems: some basic considerations. Agric Syst. 1993;41:239–55. https://doi.org/10.1016/0308-521X(93)90002-J
3. Biswas T, Majumder A, Dey S, Mandal A, Ray S, Kapoor P, et al. Evaluation of management practices in rice–wheat cropping system using multicriteria decision-making methods in conservation agriculture. Sci Rep. 2024;14:8600. https://doi.org/10.1038/s41598-024-58022-w
4. Springmann M, Clark M, Mason-D'Croz D, Wiebe K, Bodirsky BL, Lassaletta L, et al. Options for keeping the food system within environmental limits. Nature. 2018;562:519–25. https://doi.org/10.1038/s41586-018-0594-0
5. Ishizaka A, Nemery P. Multi-criteria decision analysis: methods and software. Hoboken: John Wiley & Sons; 2013. https://doi.org/10.1002/9781118644898
6. Biswas T, Ishizaka A, Majumder A, Mandal B, Dey S, Mukherjee S, et al. The PROMETHEE-GAIA: A multi-criteria decision-making method for identifying best conservation agricultural practices. Soil Tillage Res. 2025;245:106315. https://doi.org/10.1016/j.still.2024.106315
7. Bhaskar AS, Khan A. Comparative analysis of hybrid MCDM methods in material selection for dental applications. Expert Syst Appl. 2022;209:118268. https://doi.org/10.1016/j.eswa.2022.118268
8. Zoma F, Sawadogo M. A multicriteria approach for biomass availability assessment and selection for energy production in Burkina Faso: A hybrid AHP-TOPSIS approach. Heliyon. 2023;9:1–17. https://doi.org/10.1016/j.heliyon.2023.e20999
9. Seyedmohammadi J, Sarmadian F, Jafarzadeh AA, Ghorbani MA, Shahbazi F. Application of SAW, TOPSIS and fuzzy TOPSIS models in cultivation priority planning for maize, rapeseed and soybean crops. Geoderma. 2018;310:178–90. https://doi.org/10.1016/j.geoderma.2017.09.012
10. Kundu CK, Majumder A, Nath R, Gunri S, Mondal TK. Assessment of weeds of different kinds in mulberry cultivation based on multiple indicators. Indian Biol. 2005;37:45–50.
11. Srisawat C, Payakpate J. Comparison of MCDM methods for intercrop selection in rubber plantations. J Inform Commun Technol. 2016;15:165–82. https://doi.org/10.32890/jict2016.15.1.8
12. Davarpanah S, Bonab S, Khodaverdizadeh M. Assessment and comparison of sustainable agriculture approach using a combination of AHP and TOPSIS. Int Acad J Econ. 2016;3:7–18.
13. Magableh GM. An integrated model for rice supplier selection strategies and a comparative analysis of fuzzy multicriteria decision -making approaches based on the fuzzy entropy weight method for evaluating rice suppliers. PLoS One. 2024;19:1–26. https://doi.org/10.1371/journal.pone.0301930
14. Azadi A, Jalili AS, Navidi MN. Land evaluation approaches comparing TOPSIS and SAW with parametric methods for rice cultivation. Environ Monit Assess. 2023;195:1296. https://doi.org/10.1007/s10661-023-11849-8
15. Kang D, Jaisankar R, Murugesan V, Suvitha K, Narayanamoorthy S, Omar AH, et al. A novel MCDM approach to selecting a biodegradable dynamic plastic product: a probabilistic hesitant fuzzy set-based COPRAS method. J Environ Manag. 2023;340:117967. https://doi.org/10.1016/j.jenvman.2023.117967
16. Tercan E, Dengiz O. Determination of rice (*Oryza sativa* L.) site suitability using multi-criteria decision-making based on the best-worst method. Geocarto Int. 2022;37:15982–98. https://doi.org/10.1080/10106049.2022.2104389
17. Ozkan B, Dengiz O, Demirag Turan I. Site suitability assessment and mapping for rice cultivation using multi-criteria decision analysis based on fuzzy-AHP and TOPSIS approaches under semihumid ecological condition in delta plain. Paddy Water Environ. 2019;17:665–76. https://doi.org/10.1007/s10333-019-00692-8
18. Maddahi Z, Jalalian A, Zarkesh M, Kheirkhah M, Honarjo N. Land suitability analysis for rice cultivation using a GIS-based fuzzy multi-criteria decision-making approach: central part of Amol District, Iran. Soil Water Res. 2017;12:29–38. https://doi.org/10.17221/1/2016-SWR
19. Qureshi MRN, Singh RK, Hasan MA. Decision support model to select crop pattern for sustainable agricultural practices using fuzzy MCDM. Environ Dev Sustain. 2018;20:641–59. https://doi.org/10.1007/s10668-016-9903-7
20. Hwang CL, Yoon K. Multiple attribute decision making: methods and applications-A state-of-the-art survey. Berlin: Springer Science & Business Media; 2012. p. 186.
21. Saaty T. The analytic hierarchy process (AHP) for decision making. Kobe: University of Pittsburgh; 1980. p. 1–69.
22. Afshari A, Mojahed M, Yusuff RM. Simple additive weighting approach to personnel selection problem. Int J Innov Manag Technol. 2010;1:511.
23. Haque ME, Bell RW, Islam MA, Rahman MA. Minimum tillage unpuddled transplanting: an alternative crop establishment strategy for rice in conservation agriculture cropping systems. Field Crops Res. 2016;185:31–9. https://doi.org/10.1016/j.fcr.2015.10.018
24. Calcante A, Oberti R. A technical-economic comparison between

conventional tillage and conservative techniques in paddy-rice production practice in northern Italy. Agronomy. 2019;9:886. https://doi.org/10.3390/agronomy9120886

25. Kumar R, Choudhary JS, Mishra JS, Mondal S, Poonia S, Monobrullah M, et al. Outburst of pest populations in rice-based cropping systems under conservation agricultural practices in the middle Indo-Gangetic Plains of South Asia. Sci Rep. 2022;12:3753. https://doi.org/10.1038/s41598-022-07760-w

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.