



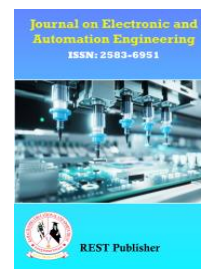
Journal on Electronic and Automation Engineering

Vol: 4(4), December 2025

REST Publisher; ISSN: 2583-6951 (Online)

Website: <https://restpublisher.com/journals/jae/>

DOI: <https://doi.org/10.46632/jae/4/4/5>



Comparative Analysis of Climate Change Impacts on Soil Erosion in Merku Thodarchi Malai with Changes in Crop Management Using TOPSIS Method

*Nathiya Murali, Sathiyaraj Chinnasamy, M. Ramachandran, Anusuya Mohan

REST Labs, Kaveripattinam, Krishnagiri, Tamil Nadu, India.

*Corresponding Author Email: nathiyamurali6775@gmail.com

Abstract: Climate change has emerged as a critical global challenge, significantly impacting ecosystems, agriculture, and soil health. The Meru mountain range, an environmentally sensitive region, has experienced notable shifts in climate patterns, raising concerns about increasing soil erosion and its implications for sustainable crop management. This study investigates the impact of climate change on soil erosion dynamics in the Meru mountain range and proposes an effective crop management strategy using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. The research integrates geographical analysis, field studies, and historical climate data to estimate soil erosion rates under varying climatic conditions. The results indicate a significant increase in soil erosion driven by extreme rainfall events, which increases surface runoff and accelerates soil loss. To address these challenges, a TOPSIS-based multi-criteria decision-making framework is employed to evaluate and rank ten agricultural management alternatives. The alternatives include conventional tillage, no-till farming, crop rotation, cover cropping, mulching, agroforestry, organic farming, integrated pest management, precision agriculture, and controlled traffic farming. The evaluation criteria comprise erosion rate, crop yield, carbon sequestration, water use efficiency, organic matter content, and cost. The findings show that organic farming ranks highest, indicating its superior performance in mitigating soil erosion while maintaining productivity. This study exemplifies the effectiveness of integrating climate analysis with decision-support tools to enhance sustainable agriculture and climate adaptation strategies.

Key words: Climate Change Impacts, small-scale crop–livestock systems, biomass ratio and MCDM

1. INTRODUCTION

The main technical obstacle in meeting future meat and milk demands continues to be the producers' challenge in consistently providing adequate nourishment for animals throughout the year. Enhancing the availability and quality of animal feed serves as an effective strategy for boosting livestock productivity and accumulating valuable assets. This article aims to briefly evaluate the significance of crop residues as a feed resource and to outline the factors in crop management that impact the yield and quality of these residues. The utilization of crop residues as animal feed is on the rise. Globally, more than one billion metric tonnes of residues are generated, serving as a crucial source of feed for ruminants in developing nations. Regrettably, the nutritional value of crop residues has been largely overlooked, leading to the development of crop varieties and hybrids that yield fewer residues compared to unimproved varieties. Nevertheless, crop residues remain a paramount source of feed for ruminants in the context of small-scale crop–livestock systems in India. Reaping numerous advantages from cultivating cover crops relies on selecting the right species and employing proper management techniques. In colder climates of northern latitudes during the winter season, optimal choices for cover crops include rye, clover, or vetch. These crops are sown in autumn to provide protection throughout the winter months. In tropical regions with dry seasons, suitable cover crops encompass legumes such as Pueraria, Stylosanthes, and Centrosema, as well as grasses like Brachiaria, Melinis, and Panicum. Research conducted in Ohio highlighted tall fescue and smooth bromegrass as the most favorable among various cover crops due to their deep root systems, higher root-to-shoot biomass ratio, and significant contributions to soil organic carbon sequestration, soil structure enhancement, microaggregation, and erosion prevention. Employing these grasses also aids in erosion control. To effectively establish grain or food

crops, one management approach involves utilizing cover crops as a live mulch. Alternatively, cover crops can be chemically or mechanically terminated upon planting the grain crop. The success of the live mulch method hinges on its ability to avoid competing for light, moisture, and nutrients. Crop management practices are commonly discussed within a section referred to as "management options." However, this term is quite broad and encompasses a wide range of meanings. The simplest and most frequently employed approach involves representing crop management practices as unchanging parameters of the crop model. These parameter values are established prior to any simulation and remain constant; they are not influenced by the crop's condition. To avoid the need for predetermined values for decision parameters and to connect them with the crop's environmental changes, decision rules are utilized. When developing crop management strategies using models, there are four key considerations to bear in mind. The first is accurately describing the relevant system, which depends on the specific question being addressed (including processes, timeframes, spatial scales, limitations, and boundaries). The second involves constructing a suitable "in silico" experimental simulation plan (virtual design) with the goal of creating crop management strategies. Crop stress, arising from factors such as crop diseases, insufficient water supply, insect infestations, and other issues, often becomes evident through a reduction in the transpiration rate of the crop. Consequently, significant efforts have been directed towards employing remote sensing techniques to monitor the rates of crop evapotranspiration. One particularly promising method for practical implementation involves utilizing remotely gathered crop coefficients (which express the ratio of actual crop evapotranspiration to that of a reference crop) to estimate the specific evapotranspiration rate of the crop at a given location, using easily accessible meteorological data. This approach only necessitates the measurement of a spectral vegetation index (such as NDVI) and essentially enhances an existing method already adopted by farmers for crop management. These enhancements result in improved accuracy of evaporation estimates and, by utilizing images, enable the mapping of variations both within and between fields. The model presumed that growth is not restricted by water and nitrogen availability. While this holds true for well-watered and heavily fertilized crops, which are characteristic of much of Australia's cotton production, there are instances where irrigation water is insufficient and nitrogen deficiency due to denitrification or inadequate fertilization could result in a crop lacking nitrogen. These scarcities in water or nitrogen affect a crop's ability to compensate for damage caused by pests, and such factors should be considered when making pest management decisions. Additionally, when facing reduced irrigation water resources, choices must be made regarding the crop's cultivation area. Interest in rain-fed cotton is on the rise in Australia; determining suitable regions and optimal planting dates is essential, along with assessing associated risks.

2. MATERIALS AND METHOD

Materials: The assessment factors erosion rate (C1), agricultural yield (C2), carbon capture (C3), water efficiency (C4), organic content (C5), and cost-effectiveness (C6) are employed to appraise the options including traditional tillage (A1), no-plow farming (A2), crop sequencing (A3), intercropping (A4), soil covering (A5), agroforestry integration (A6), natural farming (A7), holistic pest control (A8), precision farming (A9), and controlled machinery movement (A10) in the context of the influence of climate change on soil erosion in the Merku Thodarchi Malai region, taking into account alterations in crop management practices.

Alternative:

Traditional Tillage (A1): The conventional method involving plowing and mechanical disruption of soil.

No-Plow Farming (A2): A method where crops are cultivated without soil disturbance through plowing or tilling.

Crop Sequencing (A3): Rotating different crops in a specific order to enhance soil health and control pests.

Cover Crop Planting (A4): Introducing protective crops between main ones to shield soil, enhance fertility, and prevent erosion.

Soil Covering (A5): Applying organic or synthetic materials on the ground to retain moisture, suppress weeds, and enhance soil quality.

Agroforestry Integration (A6): Combining trees or shrubs with crops or livestock for a more sustainable and productive farming approach.

Natural Farming (A7): Employing organic methods, prioritizing soil health, biodiversity, and ecological balance.

Holistic Pest Management (A8): An all-encompassing pest control strategy that blends diverse tactics to reduce reliance on pesticides.

Precision Farming (A9): Utilizing technology and data for optimal use of resources like water, fertilizers, and pesticides.

Controlled Machinery Movement (A10): Limiting heavy equipment to designated lanes to decrease soil compression and safeguard soil structure.

Evaluation Criteria

Erosion Rate (C1): The speed of soil erosion caused by wind or water, leading to loss of valuable topsoil.

Agricultural Yield (C2): Quantity of farm produce (e.g., grains, fruits) harvested per unit of land.

Carbon Capture (C3): The process of gathering and retaining carbon dioxide from the atmosphere, often within soil or plants, to combat climate change.

Water Efficiency (C4): Agricultural output (crop yield) achieved per unit of water consumption.

Organic Content (C5): Proportion of decomposed plant and animal matter within the soil, crucial for fertility and structure.

Cost-effectiveness (C6): The economic implications linked to implementing and maintaining various agricultural approaches.

These evaluation criteria serve to gauge the effects of different farming practices on sustainability facets like soil vitality, environmental repercussions, resource efficiency, and economic feasibility. Researchers, policymakers, and farmers can leverage these indicators to make well-informed choices regarding suitable practices, aligned with their particular objectives and local circumstances.

Method: Utilizing the TOPSIS technique holds significance in enhancing software efficiency by leveraging its efficiency attributes and aiding critical decision-making in problem-solving scenarios. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method, conceived by Hwang and Yoon in 1981, stands out for its exceptional attributes in contrast to other methods. It serves as a multi-criteria decision-making analysis approach. TOPSIS functions by pinpointing the optimal alternative based on a balanced solution. The core premise of the TOPSIS methodology revolves around selecting an alternative variant that minimizes the Euclidean distance from the positive ideal solution while maximizing the distance from the negative ideal solution. The negative ideal solution pertains to the maximization of the loss criterion and the minimization of profitability, whereas the positive ideal solution focuses on maximizing profitability and minimizing the loss criterion. This method establishes an index that lies closer to the positive ideal solution while maintaining a substantial distance from the negative ideal solution. Ultimately, the TOPSIS method facilitates the selection of the alternative that aligns closely with the positive ideal solution. The compromise solution can be interpreted as choosing a solution that maximizes the Euclidean distance from the negative ideal solution and minimizes it from the positive ideal solution. This technique is crucial for making decisions based on intervals and intuitive reasoning, using real number weights. It's rare to find methods for multi-attribute interval vague set decision making where both the weights and attribute values are interval vague values. This study proposes a novel approach using the TOPSIS method to address multiattribute decision making. Initially, the interval vague attribute values are weighted according to interval value operation rules. Ideal and negative solutions are then identified using a score function. Next, the concept of distance for interval vague values is introduced, and distances between each project and the ideal/negative ideal solutions are computed. Employing the TOPSIS method, relative adjacent degrees are calculated, followed by determining the project order based on these degrees. Specifically, an extension of the TOPSIS technique within a fuzzy context has been embraced. Numerous scholars have formulated a similarity-to-ideal-solution model adaptable to the fuzzy realm and have deployed it across diverse domains. Chen further elaborated the TOPSIS approach for resolving decision-making quandaries within a fuzzy framework. As per this theory, the attributes are represented as TFNs (Triangular Fuzzy Numbers), employing a linear normalization approach, while a vertex method is introduced for computing distance measurements to establish the ultimate ranking. Concurrently, a secondary normalization methodology is drawn from the work of Jahanshahloo et al. This paper stands out as one of the earliest instances of applying the fuzzy TOPSIS method to tackle issues pertaining to water management or hydraulic scenarios. A multi-criteria decision making (MCDM) technique is employed to arrange different parameters in a specific order. The method known as TOPSIS, initially proposed as a widely used MCDM approach by Hwang and Yoon (1981), was introduced by Chen (2000) to address MCDM challenges in situations of uncertainty and ambiguity. Nowadays, various researchers are utilizing data with the TOPSIS method. This study considers 6 criteria and 10 alternatives. The TOPSIS approach is then implemented to address complex issues in this context. Prior to its application, the assumptions of the TOPSIS method are verified, including the interrelationships between independent and dependent factors, as well as the initial steps of the method.

3. RESULT AND DISCUSSION

TABLE 1. Crop Management

	C1	C2	C3	C4	C5	C6
A1	25	10	300	0.8	2.5	500
A2	40	15	400	1.2	2.8	700
A3	20	12	350	1.0	3.2	600
A4	30	14	380	1.1	3.0	550
A5	35	17	370	1.3	2.7	650
A6	15	18	450	1.4	3.5	800
A7	10	20	500	1.5	3.8	900
A8	22	11	320	0.9	2.9	550
A9	28	16	420	1.2	3.1	700
A10	18	17	480	1.3	3.3	750

Shows the table 1. Crop Management Using TOPSIS Method. Conventional tillage involves mechanical soil disturbance, which can lead to higher erosion rates, lower crop yields, and reduced carbon sequestration. The water use efficiency is comparatively lower due to increased evaporation, and organic matter content may decline. The cost is moderate. No-till farming minimizes soil disturbance, reducing erosion and improving carbon sequestration. Higher crop yields and better water use efficiency are achievable. Organic matter content tends to be higher, but initial implementation costs can be higher as well. Crop rotation entails cultivating various crops in a particular order to boost soil richness and mitigate erosion. It leads to moderate improvements in yield and water use efficiency, while maintaining organic matter levels. Water use efficiency may be slightly lower, but organic matter content is relatively maintained. Precision agriculture utilizes technology for targeted inputs, optimizing crop growth. Erosion rates are moderate, while crop yields, carbon sequestration, and water use efficiency are improved. Organic matter content is also favorable. Controlled traffic farming limits machinery traffic to specific paths, reducing soil compaction and erosion. It results in low erosion rates, high crop yields, and significant carbon sequestration. Water use efficiency and organic matter content are also favorable, but costs can be higher due to precision equipment.

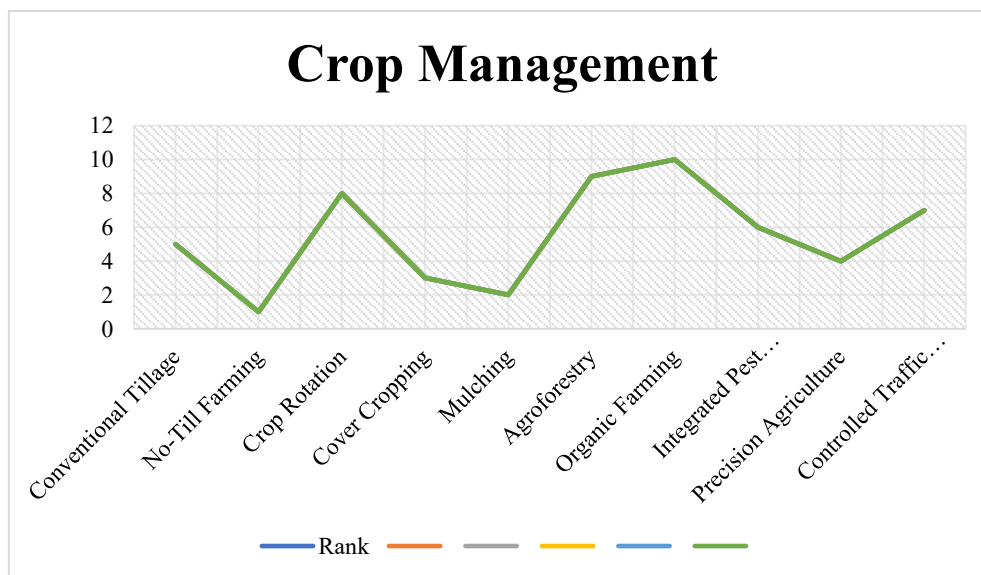


FIGURE 1. Crop management

Shows the figure 1. Crop management for using TOPSIS method. The alternatives are conventional tillage, no-till farming, crop rotation, cover cropping, mulching, agroforestry, organic farming, integrated pest management, precision agriculture and controlled traffic farming. The evaluation parameters are erosion rate (%), crop yield (%), carbon sequestration (kg co2/ha), water use efficiency (m3/kg), organic matter (%) and cost (usd/ha)

TABLE 2. Square value

	Square value					
A1	625.0	100.0	90000.0	0.6400	6.2500	250000.0
A2	1600.0	225.0	160000.0	1.4400	7.8400	490000.0
A3	400.0	144.0	122500.0	1.0000	10.2400	360000.0
A4	900.0	196.0	144400.0	1.2100	9.0000	302500.0
A5	1225.0	289.0	136900.0	1.6900	7.2900	422500.0
A6	225.0	324.0	202500.0	1.9600	12.2500	640000.0
A7	100.0	400.0	250000.0	2.2500	14.4400	810000.0
A8	484.0	121.0	102400.0	0.8100	8.4100	302500.0
A9	784.0	256.0	176400.0	1.4400	9.6100	490000.0
A10	324.0	289.0	230400.0	1.6900	10.8900	562500.0

Table 2 presents the squared values of the decision matrix corresponding to ten agricultural management alternatives (A1–A10) across the selected evaluation criteria. Squaring the original values is an essential step in the normalization process of the TOPSIS method, as it helps to eliminate scale differences between the criteria. The results show considerable variation among the alternatives, indicating differing performance in erosion control, yield, carbon sequestration, water use efficiency, organic matter, and cost. Higher squared values reflect a stronger influence or magnitude of the respective criterion for a given alternative. These squared values are then used to calculate the normalized weights, ensuring a balanced and unbiased multi-criteria evaluation.

TABLE 3. Normalized Data

	Normalized Data					
A1	0.3062	0.2065	0.2360	0.2128	0.2549	0.2324
A2	0.4899	0.3098	0.3147	0.3192	0.2854	0.3253
A3	0.2449	0.2479	0.2754	0.2660	0.3262	0.2788
A4	0.3674	0.2892	0.2990	0.2926	0.3058	0.2556
A5	0.4286	0.3511	0.2911	0.3458	0.2753	0.3021
A6	0.1837	0.3718	0.3540	0.3724	0.3568	0.3718
A7	0.1225	0.4131	0.3934	0.3990	0.3874	0.4183
A8	0.2694	0.2272	0.2518	0.2394	0.2956	0.2556
A9	0.3429	0.3305	0.3304	0.3192	0.3160	0.3253
A10	0.2204	0.3511	0.3776	0.3458	0.3364	0.3486

Table 3 Normalized Data shows the informational set for the alternatives are conventional tillage, no-till farming, crop rotation, cover cropping, mulching, agroforestry, organic farming, integrated pest management, precision agriculture and controlled traffic farming. The evaluation parameters are erosion rate (%), crop yield (%), carbon sequestration (kg co2/ha), water use efficiency (m3/kg), organic matter (%) and cost (usd/ha).

TABLE 4. Weight

	Weight					
A1	0.25	0.25	0.25	0.25	0.25	0.25
A2	0.25	0.25	0.25	0.25	0.25	0.25
A3	0.25	0.25	0.25	0.25	0.25	0.25
A4	0.25	0.25	0.25	0.25	0.25	0.25
A5	0.25	0.25	0.25	0.25	0.25	0.25
A6	0.25	0.25	0.25	0.25	0.25	0.25
A7	0.25	0.25	0.25	0.25	0.25	0.25
A8	0.25	0.25	0.25	0.25	0.25	0.25
A9	0.25	0.25	0.25	0.25	0.25	0.25
A10	0.25	0.25	0.25	0.25	0.25	0.25

Table 4 provides the weight distribution assigned to the evaluation criteria for the ten alternatives (A1–A10). An equal weight of 0.25 is assigned to each criterion, indicating that all factors are considered equally important in the decision-making process. This uniform weighting approach ensures that no single criterion disproportionately influences the overall evaluation results. By using equal weights, the analysis maintains objectivity and provides a balanced evaluation framework within the TOPSIS method. These weights are then used to calculate the weighted normalized decision matrix, which forms the basis for determining the relative performance and ranking of the alternatives.

TABLE 5. Weighted normalized decision matrix

	Weighted normalized decision matrix					
A1	0.0765	0.0516	0.0590	0.0532	0.0637	0.0581
A2	0.1225	0.0775	0.0787	0.0798	0.0714	0.0813
A3	0.0612	0.0620	0.0688	0.0665	0.0816	0.0697
A4	0.0919	0.0723	0.0747	0.0732	0.0765	0.0639
A5	0.1072	0.0878	0.0728	0.0865	0.0688	0.0755
A6	0.0459	0.0929	0.0885	0.0931	0.0892	0.0929
A7	0.0306	0.1033	0.0983	0.0998	0.0968	0.1046
A8	0.0674	0.0568	0.0629	0.0599	0.0739	0.0639
A9	0.0857	0.0826	0.0826	0.0798	0.0790	0.0813
A10	0.0551	0.0878	0.0944	0.0865	0.0841	0.0871

Table 5 Weighted normalized decision matrix shows the informational set for the Normalized Data multiplication Weight we used the formula.

TABLE 6. Positive & negative matrix

	C1	C2	C3	C4	C5	C6
Positive	0.1225	0.1033	0.0983	0.0532	0.0637	0.0581
Negative	0.0306	0.0516	0.0590	0.0998	0.0968	0.1046

Show the table 6 crop management for using TOPSIS method positive and negative matrix value. This row represents the positive aspects or factors being measured for each of the attributes. The values in this row (0.1225, 0.1033, 0.0983, 0.0532, 0.0637, 0.0581) could represent the strength, percentage, or some other form of measurement of these positive aspects within the respective attributes. This row represents the negative aspects or factors being measured for each of the attributes. The values in this row (0.0306, 0.0516, 0.0590, 0.0998, 0.0968, 0.1046) could similarly represent the strength, percentage, or measurement of these negative aspects within the respective attributes.

TABLE 7. Si positive, Si negative, Ci and Rank

	Si Positive	Si Negative	Ci	Rank
A1	0.0795	0.0868	0.5219	5
A2	0.0486	0.1050	0.6837	1
A3	0.0834	0.0600	0.4185	8
A4	0.0552	0.0844	0.6046	3
A5	0.0506	0.0955	0.6536	2
A6	0.0976	0.0551	0.3608	9
A7	0.1177	0.0649	0.3555	10
A8	0.0814	0.0711	0.4661	6
A9	0.0592	0.0759	0.5617	4
A10	0.0846	0.0614	0.4205	7

Show the table 7 Si positive, Si negative, Ci and rank. This likely refers to the "Sustainability Index" or a similar metric that measures the positive impact or effectiveness of a specific crop management strategy. It's a measure of how well a particular strategy promotes sustainable agricultural practices, environmental health, or other positive outcomes. The values in the table (ranging from 0.05 to 0.12) indicate the Si Positive scores for each strategy. Higher values generally imply more positive impact or effectiveness. This likely refers to the "Negative Sustainability Index" or a similar metric that measures the negative impact or drawbacks of a specific crop management strategy. It's a measure of potential harmful effects on the environment, ecosystem, or other negative outcomes. The values in the table (ranging from 0.06 to 0.11) indicate the Si Negative scores for each strategy. Lower values generally imply fewer negative impacts. This likely refers to the "Crop Intensity" or a similar metric that measures the intensity of crop production or resource use associated with a specific strategy. It's a measure of how efficiently resources (such as water, fertilizers, labor) are used to produce crops. The values in the table (ranging from 0.36 to 0.68) indicate the Ci values for each strategy. Lower values generally imply more efficient resource use. No-Till Farming (A2) is got first rank and Organic Farming (A7) is got lowest rank.

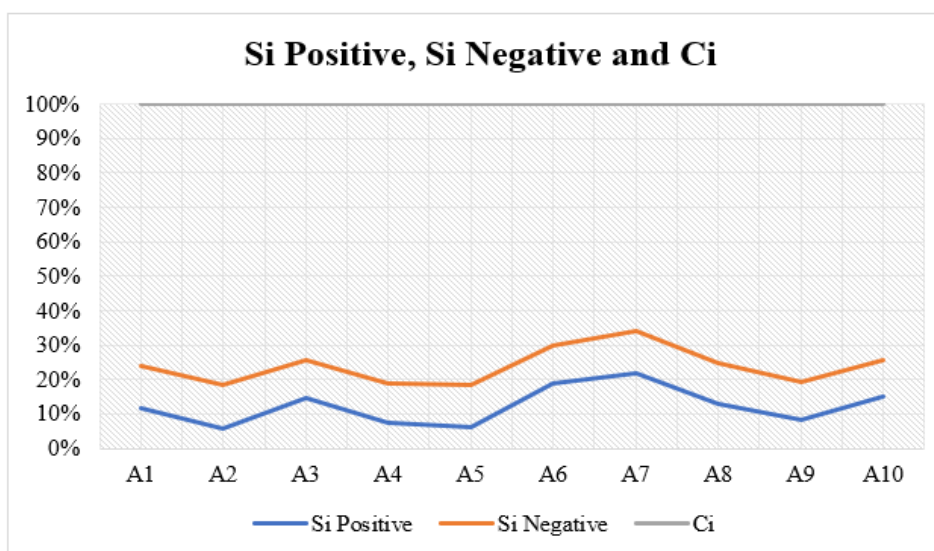


FIGURE 2. Si positive, Si negative and Ci value

Show the Figure 2 illustrating Si in the affirmative, Si in the opposing, and Ci. This likely refers to the "Sustainability Index" or a similar metric that measures the positive impact or effectiveness of a specific crop management strategy. It's a measure of how well a particular strategy promotes sustainable agricultural practices, environmental health, or other positive outcomes. The values in the table (ranging from 0.05 to 0.12) indicate the Si Positive scores for each strategy. Higher values generally imply more positive impact or effectiveness. This likely refers to the "Negative Sustainability Index" or a similar metric that measures the negative impact or drawbacks of a specific crop management strategy. It's a measure of potential harmful effects on the environment, ecosystem, or other negative outcomes. The values in the table (ranging from 0.06 to 0.11) indicate the Si Negative scores for each strategy. Lower values generally imply fewer negative impacts. This likely refers to the "Crop Intensity" or a similar metric that measures the intensity of crop production or resource use associated with a specific strategy. It's a measure of how efficiently resources (such as water, fertilizers, labor) are used to produce crops. The values in the table (ranging from 0.36 to 0.68) indicate the Ci values for each strategy. Lower values generally imply more efficient resource use.

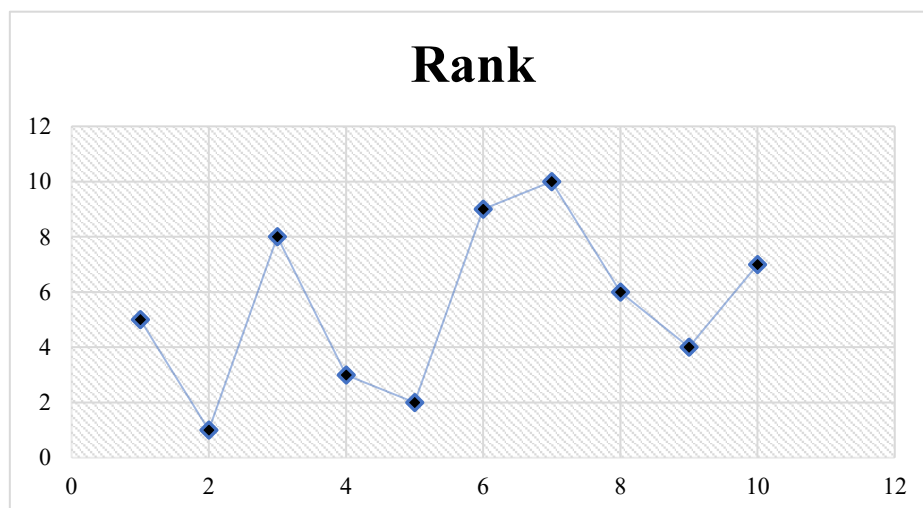


FIGURE 3. Rank

Shows the figure 3 crop management using TOPSIS method final result. No-Till Farming is got first rank, Mulching is got second rank, Cover Cropping is got third rank, Precision Agriculture is got fourth rank, Conventional Tillage is got fifth rank, Integrated Pest Management is got sixth rank, Controlled Traffic Farming is got seventh rank, Crop Rotation is got eighth rank, Agroforestry is got ninth rank and Organic Farming is got lowest rank.

4. CONCLUSION

The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method emerges as a robust and effective tool for addressing the intricate and multifaceted challenges posed by climate change on crop management. This study embarked on an exploration of the significant impacts of climate change on agricultural practices, emphasizing the urgency of innovative solutions to sustainably enhance crop productivity and ensure food security in the face of changing environmental conditions. Which culminate in disruptions to traditional crop management strategies. The vulnerability of crop yields to these changes necessitates a systematic and adaptive approach that takes into account multiple criteria and objectives, ranging from yield potential and resource efficiency to environmental resilience and socio-economic factors. The application of the TOPSIS method proved instrumental in guiding decision-makers towards well-informed and balanced choices in crop management. By evaluating diverse alternatives and ranking them based on their proximity to the ideal solution, TOPSIS offers a comprehensive framework that integrates both quantitative and qualitative parameters. This holistic approach empowers stakeholders to optimize their strategies by identifying the most suitable crop varieties, irrigation techniques, and cultivation practices that align with the evolving climate reality. However, it is essential to acknowledge that while TOPSIS offers a powerful analytical tool, its efficacy lies in the quality and accuracy of the data input. Continual monitoring, data collection, and refinement of the method are imperative to maintain its relevance and applicability in an ever-changing climate landscape. The amalgamation of climate change impacts and the TOPSIS methodology presents a promising avenue for resilient crop management in the context of environmental uncertainty. This research underscores the paramount importance of proactive adaptation, collaborative efforts, and evidence-based decision-making to mitigate the adverse effects of climate change on crop productivity. As we navigate an era of unprecedented climatic shifts, embracing innovative approaches like TOPSIS will be pivotal in cultivating a sustainable agricultural future that safeguards both global food security and ecological equilibrium. No-Till Farming is got first rank and Organic Farming is got lowest rank.

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