PLANT SCIENCE TODAY
Vol 12(sp1): 1-6
https://doi.org/10.14719/pst.9128

eISSN 2348-1900

RESEARCH ARTICLE

# Impact of conservation agriculture practices on maize in semi-arid tropics of Tamil Nadu

**Sivakumar K[1*], Vasanth P[2], Marimuthu S[1] & Suresh Kumar B T[1]**

[1]Department of Agronomy, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Chengalpattu 603 201,Tamil Nadu, India
[2]Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram 608 002, Tamil Nadu, India

*Correspondence email - sivajacks@gmail.com

Received: 26 April 2025; Accepted: 26 August 2025; Available online: Version 1.0: 07 October 2025

**Cite this article:** Sivakumar K, Vasanth P, Marimuthu S, Suresh KBT. Impact of conservation agriculture practices on maize in semi-arid tropics of Tamil Nadu. Plant Science Today. 2025; 12(sp1): 1-6. https://doi.org/10.14719/pst.9128

## Abstract

Conservation agriculture (CA) holds promise for improving soil health and crop yields in the semi-arid tropics, particularly in regions of Tamil Nadu, where rainfed agriculture is common. Studies emphasize the impact of conservation agriculture practices, such as minimum tillage and residue management, on maize production in this region. Focusing on the optimal treatment of minimum tillage combined with an irrigation water to cumulative pan evaporation (IW/CPE) ratio of 0.8, pre-emergence herbicide application, followed by one hand weeding and the application of 100 % Recommended Dose of Fertilizers (RDF). Results indicate that this integrated approach significantly enhances various growth parameters, notably plant height and Dry Matter Production (DMP), leading to substantial increases in maize yield. Comprehensive analyses reveal that the specified combination not only improves the physical attributes of maize plants but also optimizes the nutrient uptake efficiency, particularly in nitrogen, phosphorus and potassium. Statistical analysis using Principal Component Analysis (PCA) demonstrates that this treatment yields the highest positive correlations with the measured growth traits and nutrient levels, suggesting its effectiveness over alternative farming practices. The findings underscore the potential of these conservation practices to improve crop resilience and productivity in the region, addressing the challenges posed by variable climatic conditions. By implementing this sustainable agriculture framework, farmers can enhance maize productivity, thus contributing to food security while promoting environmental sustainability in the semi-arid tropics. This research advocates for a broader adoption of such conservation agriculture strategies in similar agro-ecological zones to maximize resource use efficiency and agricultural outputs, thereby improving farmer livelihoods and ensuring sustainable maize production in Tamil Nadu.

**Keywords:** maize; nutrient; principal component analysis; soil enzyme

## Introduction

Conservation agriculture (CA) is being increasingly recognized as a sustainable agricultural approach that can address the challenges of climate change, declining soil health and water scarcity, particularly in the vulnerable semi-arid tropics. In these regions, characterized by erratic rainfall, high temperatures and degraded soils, conventional agricultural practices often lead to soil erosion, reduced water infiltration and decreased crop yields (1). Conservation agriculture, with its three core principles of minimum soil disturbance, permanent soil cover and crop diversification, offers a pathway to improve soil health, conserve water and enhance crop productivity (2). Maize (*Zea mays* L.) is a vital cereal crop extensively cultivated and consumed worldwide, playing a significant role in food security and industrial applications (3, 4). Tamil Nadu, a state in southern India with substantial semi-arid areas, relies on maize as a crucial crop for both human consumption and livestock feed (4). However, the productivity of maize in Tamil Nadu's semi-arid regions is often constrained by climate variability, poor soil fertility and unsustainable farming practices (5). Therefore, exploring and promoting conservation agriculture practices for maize cultivation in these areas is essential to ensure sustainable agricultural production and to improve the livelihoods of farmers (1).

The adoption of conservation agriculture practices in semi-arid regions can lead to several benefits, including improved soil moisture retention, reduced soil erosion, enhanced soil organic carbon sequestration and increased nutrient availability (2). Minimum tillage, a key component of conservation agriculture, reduces soil disturbance, preserving soil structure and minimizing water loss through evaporation. Permanent soil cover, achieved through retaining crop residues or using cover crops, protects the soil surface from erosion, moderates soil temperature and suppresses weed growth (1). Crop diversification, involving the cultivation of multiple crops in rotation or intercropping systems, enhances biodiversity, improves soil health and reduces the risk of crop failure (6). When implemented effectively, conservation agriculture practices can lead to higher maize yields, improved water productivity and increased resilience to climate change in the semi-arid tropics of Tamil Nadu (2). This approach can contribute to climate change mitigation by reducing $CO_2$ emissions through decreased diesel use and enhanced soil organic carbon (1).

Several studies have highlighted the potential of conservation agriculture practices to enhance maize production in semi-arid environments (7-9). For instance, research has demonstrated that minimum tillage and residue retention can significantly reduce runoff, increase soil moisture and improve soil organic carbon content compared to conventional tillage practices (1). Additionally, intercropping maize with legumes can enhance nutrient availability, suppress weeds and increase overall system productivity (6). The impact of climate variability on maize yield in Tamil Nadu has been studied using panel regression analysis, with results showing that high rainfall can lead to increased maize yield, depending on temperature levels during the northeast monsoon season (4). Furthermore, the integration of organic and inorganic nutrient sources has been shown to enhance maize growth and yield components, with the highest grain yield achieved through the application of fish pond silt and vermicompost along with the recommended dose of NPK (10).

However, the adoption of conservation agriculture practices in Tamil Nadu's semi-arid regions presents several challenges(11, 12). Factors such as lack of awareness, limited access to resources and socio-economic constraints can hinder the widespread adoption of these practices (13). Additionally, the effectiveness of conservation agriculture practices can vary depending on soil type, climate conditions and management practices (7). Therefore, it is crucial to identify appropriate conservation agriculture practices that are tailored to the specific conditions of the semi-arid tropics of Tamil Nadu and to address the constraints that limit their adoption (1). Understanding farmers' perceptions and ensuring they receive adequate training and support are also vital for the successful implementation of sustainable agricultural methods (13). This necessitates a comprehensive approach involving research, extension services and policy interventions to promote the adoption of conservation agriculture practices and ensure sustainable maize production in the region (5).

This article aims to explore the impact of conservation agriculture practices on maize production in the semi-arid tropics of Tamil Nadu. It will review existing literature on the effects of conservation agriculture practices, such as minimum tillage, residue management and crop diversification on maize yield, soil health and water productivity. The study will also examine the challenges and opportunities associated with the adoption of conservation agriculture practices in the region and identify strategies to promote their wider implementation. By synthesizing available information and highlighting successful case studies, this article seeks to provide insights for researchers, policymakers and farmers interested in promoting sustainable maize production in the semi-arid tropics of Tamil Nadu. Ultimately, the goal is to contribute to enhancing food security, improving livelihoods and building resilience to climate change in this vulnerable region through the adoption of conservation agriculture practices (9).

## Materials and Methods

The field experiments were conducted at the Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, to evaluate the effect of conservation agriculture practices on the growth and physiological parameters of maize. The experimental field was in the Southern agro-climatic zone of Tamil Nadu at 9°54' N latitude and 78°54' E longitude and an altitude of 147 m above MSL. A mean annual rainfall of 848 mm was distributed in 46 rainy days. The soil of the experimental site is clay loam with 203.2, 16.7 and 419.6 kg available soil N, $P_2O_5$ and $K_2O$ $ha^{-1}$. The pH of the soil was 8.0 with EC of 0.37 dS m-1 and with 0.48 % soil organic carbon.

The conventional tillage comprised of one disc ploughing, two cultivators ploughing and one rotavator pass. Minimum tillage plots were prepared with the help of a mulcher and one pass with disc harrow, followed by one cultivator ploughing. The main and sub -plots were formed with irrigation and drainage channels. Maize hybrid CO H (M) 6 was used for the study. The experiments were laid out in a split-plot design with three replications. The main plot consisted of four treatments, conventional tillage with irrigation at 0.8 IW/CPE ratio ($M_1$), conventional tillage with irrigation at 0.6 IW/ CPE ratio ($M_2$), minimum tillage with irrigation at 0.8 IW/CPE ratio ($M_3$), minimum tillage with irrigation at 0.6 IW/CPE ratio ($M_4$) and the sub plot treatments consisted of six treatments *viz,* crop residue mulch with 100 % RDF ($S_1$), crop residue mulch with 75 % RDF ($S_2$), pre emergence application of pendimethalin *fb* one hand weeding along with 100 % RDF ($S_3$), pre-emergence application of pendimethalin *fb* one hand weeding along with 75 % RDF ($S_4$), mechanical weeding twice with 100 % RDF ($S_5$), mechanical weeding twice with 75% RDF ($S_6$). The PCA technique is a statistical method often used to examine a group of correlated variables. A multivariate statistical analysis method selects a smaller number of factors called principal components from among the primary factors so that the insignificant data are removed. The first basic component extracted considers the largest amount of data scattered in the entire dataset. This means that the first component is correlated with several variables. The second extracted component has two important features. First, this component considers the largest dataset that the first component had not computed and second, it is not correlated with the first component. In other words, regardless of the previous component, each component describes a smaller variance by passing from the initial component to the terminal components. The first principal component always describes the maximum variance and the last component describes the least variance.

One of the most practical statistical methods in data analysis are ANOVA's "variance analysis" technique. In this method, the total variance of the data is divided into two or more parts based on one or more factor variables. Based on tests related to variance, groups can be tested for homogeneity or heterogeneity. Tukey's least real difference tests are also famously used as a studentized statistic for all pairwise comparisons between groups and matches the experimental error rate with the collection error rate for all pairwise com parisons. The first principal component always describes the maximum variance and the last component describes the least variance. A lot of information will not be lost by deleting the last component. PCA in Excel using the XLSTAT statistical software were used for the analysis in this study.

## Results

The PCA resulted in the identification of traits, growth parameters and soil enzymes, which are presented in Fig. 1, of different maize

cultivation practices under the influence (tillage and irrigation scheduling) and (weed and nutrient management). The results of this PCA based on the correlation matrix indicated that the two main principal components with eigenvalues more than 1 (eigenvalues > 1) were related to about 90 % of the total variation in the traits. The first principal component (F1) had a significant positive effect on plant height, DMP, yield, Nitrogen, phosphorus and potassium. The second principal component (F2) had a significant positive effect on SOC, urease, phosphatase and dehydrogenase.

Based on this PCA, tillage practices and irrigation scheduling were $M_3S_3$ had a significant for the first principal component (Fig. 1A). The biplot results (Fig. 1B) on the effect of tillage practices and irrigation scheduling indicated that, with weed and nutrient application, the values of the first principal component have increased variation in the second principal component have a significant on the effect of the Minimum tillage + 0.8 IW/CPE ratio with pre-emergence application of herbicide + *fb* one hand weeding +100 % RDF). Therefore, the treatment $M_3S_3$ increased the plant height, DMP, yield, nitrogen, phosphorus and potassium compared to the treatment $M_2S_2$, minimum tillage with irrigation at 0.8 IW/CPE ratio with pre-emergence application of pendimethalin *fb* one hand weeding along with 100 % RDF.

## Discussion

The advancement of conservation agriculture practices within the semi-arid tropics of Tamil Nadu has emerged as a vital strategy for enhancing maize production while ensuring sustainable agricultural practices in the face of climate variability and limited natural resources. The focus of this research on the optimal treatment combination of minimum tillage with 0.8 (IW/CPE) ratio + pre-emergence application of herbicides, followed by one hand weeding and the application of 100 % RDF reveals significant improvements in plant height, DMP, yield and nutrient status (nitrogen, phosphorus and potassium) in maize cultivation.

The implementation of minimum tillage, a cornerstone of conservation agriculture, minimizes soil disturbance and conserves soil structure. This practice is particularly beneficial in the semi-arid tropics, where soil erosion and degradation can severely limit agricultural productivity (14, 15). By reducing compaction and enhancing aeration in the root zone, minimum tillage promotes deeper root penetration and improves overall root development. Consequently, maize plants manifest enhanced plant height and robust vegetation since the preserved soil structure significantly boosts the soil's water infiltration and retention capacity (16). When coupled with a specified irrigation strategy of 0.8 IW/CPE, this practice enhances water-use efficiency by ensuring that crops receive the necessary moisture without excessive irrigation applications (17). In regions prone to drought, optimizing irrigation is critical as it reduces farmer reliance on scarce water resources, thereby sustaining soil moisture levels that are conducive to maize growth. This balanced approach allows plants to access water during crucial growth phases, thereby supporting increased plant height. Research indicates that optimal moisture levels can enhance cell elongation and leaf area expansion, ultimately contributing to improved photosynthetic capacity and biomass accumulation (18).

The role of integrated weed management in this treatment regimen cannot be overstated. The application of pre-emergence herbicides significantly mitigates competition from weeds, which are notorious for reducing crop yield by depleting shared resources such as water and nutrients (19). By controlling weeds proactively, these herbicides allow maize plants to establish themselves effectively, leading to enhanced nutrient uptake efficiency. The subsequent inclusion of one hand weeding acts as a fail-safe measure, addressing any resistant weed populations and bolstering the overall efficacy of the weed control strategy (20). The application of 100 % RDF ensures that maize plants receive an adequate supply of essential nutrients, including nitrogen (N), phosphorus (P) and potassium (K). Nitrogen is vital for vegetative growth as it significantly influences the development of leaves and stems. Higher nitrogen availability promotes chlorophyll synthesis, which is crucial for photosynthesis, thereby leading to greater biomass production. This impact is reflected in increased DMP, as nitrogen is directly linked to the enhancement of primary metabolic functions in plants (21). Phosphorus, on the other hand, is essential for root development and energy transfer within the plant. Its application enables maize plants to establish extensive root systems, facilitating the absorption of water and nutrients from a larger soil volume. The research findings indicate that enhanced phosphorus levels correlate strongly with improved plant health and yield, particularly in nutrient-deficient soils, which are common in semi-arid agricultural systems (22). Potassium plays a multifaceted role in plant physiological processes. It regulates stomatal opening, which in turn affects transpiration rates and water use efficiency. Additionally, potassium influences enzyme function and photosynthetic processes, further driving growth and yield. The synergistic effects of balanced N, P and K nutrition under the recommended fertilization scheme accentuate the productivity of maize crops, as evidenced by the significant increments in yields observed (23). The results of this PCA based on the correlation matrix revealed that the first two principal components with eigenvalues > 1 accounted for 92.79 % of the total variation in traits. By illustrating the correlations between the treatment components and the observed improvements in maize growth metrics such as plant height, DMP and yield, PCA confirms the practicality of adopting these integrated approaches in sustainable agricultural practices. From an ecological perspective, embracing conservation agriculture practices, such as those examined in this study, contributes significantly to soil health and environmental sustainability. By minimizing soil disturbance, conserving moisture and optimizing nutrient applications, these practices not only improve maize productivity but also enhance the resilience of agricultural systems against the adversities posed by climate change (24). Moreover, the decrease in dependency on chemical inputs due to effective weed management aligns with the principles of sustainable farming by encouraging ecological balance and promoting biodiversity within agroecosystems. As the climate crisis intensifies global agricultural challenges, the methodologies explored in this research provide crucial insights into sustainable farming practices tailored for farmers in Tamil Nadu's semi-arid regions (24). This study not only verifies the tangible benefits derived from a holistic approach to maize production but also emphasizes the need for policy frameworks that support the widespread adoption of conservation

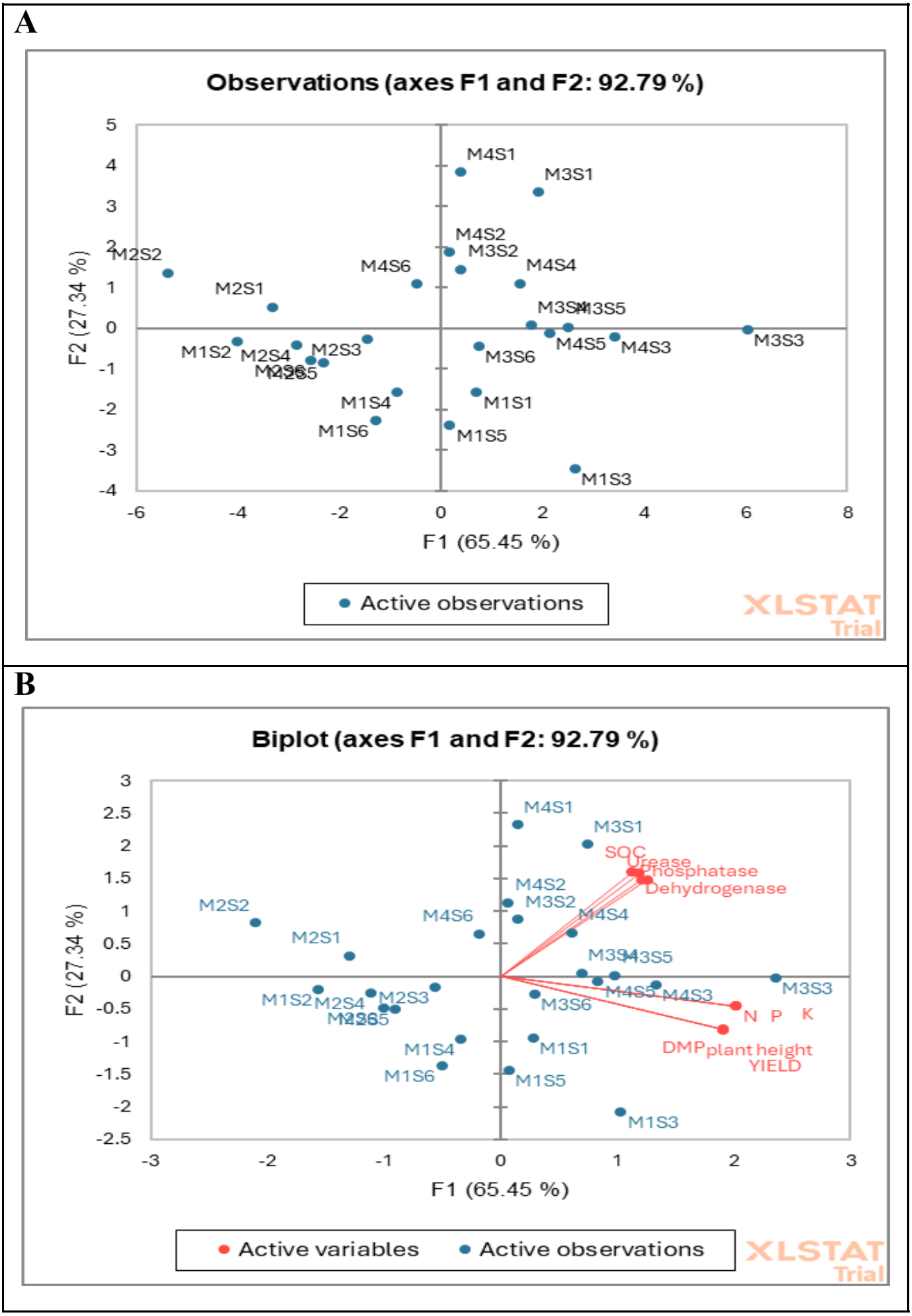


**Fig. 1.** PCA observation plot (A) and biplot (B) of the first two components performed on growth parameters and soil enzymes by different (tillage and irrigation scheduling) and (Weed and Nutrient management) on maize. Plant Height, DMP, Yield, N (Nitrogen), P (Phosphorus), K (Potassium), SOC (Soil organic compound), Urease, Phosphatase and Dehydrogenase.

agriculture. Promoting training programs for farmers, coupled with accessible resources for implementing these practices, paves the way for greater food security and socio-economic stability.

## Conclusion

In conclusion, the findings from this study highlight the powerful impact of conservation agriculture practices on maize cultivation in the semi-arid tropics of Tamil Nadu. The integration of minimum tillage, optimized irrigation strategies, pre-emergence herbicide application, supplementary weeding and balanced fertilization creates a robust framework for enhancing agricultural productivity. As stakeholders in the agricultural sector work towards sustainable solutions and improved livelihoods, the adoption of these methodologies will undoubtedly contribute to fostering a more resilient and productive agricultural landscape in Tamil Nadu.

## Acknowledgements

I would like to express my sincere gratitude to the Agricultural College and Research Institute (TNAU), Madurai, for providing access to resources and literature necessary for the completion of this research article. This research would not have been possible without their contributions and I am sincerely thankful for the opportunity to pursue this work. Their support has played a vital role in enabling me to carry out my research and complete my doctoral journey.

## Authors' contributions

SK carried out conceptualization, investigation and original drafts preparation. VP carries out supervision, Formal analysis, review editing and plagiarism checking. MS carried out conceptualization, data curation and investigation. SKBT carried out review and editing. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** The authors declare that they have no conflict of interest.

**Ethical issues:** None

## References

1. Jat RP, Wani S, Pathak P, Singh P, Sahrawat KL, Chander G, et al. Evaluating climate change mitigation and adaptation potential of conservation agriculture in semi-arid tropics of southern India. Int J Environ Climate Change. 2015;5(4):324-38. https://doi.org/10.9734/BJECC/2015/18479
2. Patil MD, Wani SP, Garg KK. Conservation agriculture for improving water productivity in Vertisols of semi-arid tropics. Curr Sci. 2016;110(9):1730-9. https://doi.org/10.18520/cs/v110/i9/1730-1739
3. Aruna Prabha S, Venkatesa Palanichamy N, Murugananthi D, Shivakumar KM, Kalpana M, Balakrishnan M. An empirical study on maize value chain in Tamil Nadu. PlantSciToday.2024;11:5872. https://doi.org/10.14719/pst.5872
4. Gurusamy P, Rudrasamy B. Effect of climate change on maize productivity: panel data analysis. Adv Res. 2020:41-5. https://doi.org/10.9734/air/2020/v21i1230280
5. Muthukumar PK. A sociological study on impact of climate change on Tamil Nadu agricultural productivity. J Pharmacogn Phytochem. 2019;8(2S):347-8.
6. Legesse Hidoto DM. Effects of maize/legume intercropping on grain yield of component crops, land productivity and profitability under conservation agriculture. World J Innov Res. 2021;11(3):46-51.
7. Kumari A, Chander GI, Laxminarayana P, Wani SP, Reddy SN, Padmaja G. Influence of tillage practices and residue management practices on yield attributes and yield of maize in maize-based cropping systems under semi-arid tropics. J Res PJTSAU. 2019;47 (3):20-6.
8. Mupangwa W, Dimes J, Walker S, Twomlow S. Measuring and simulating maize (*Zea mays* L.) yield responses to reduced tillage and mulching under semi-arid conditions. Agric Sci. 2011;2:167-74. https://doi.org/10.4236/as.2011.23023
9. Siziba S, Nyikahadzoi K, Makate C, Mango N. Impact of conservation agriculture on maize yield and food security: evidence from smallholder farmers in Zimbabwe. Afr J Agric Resour Econ. 2019;14 (2):89-105.
10. Arumugam R, Sivalingam R, Perumal C, Manivelu R. Integrated nutrient management for enhanced maize yield and sustainability in Tamil Nadu, India. Indian J Agric Res. 2025;1:9. https://doi.org/10.18805/IJARe.A-6247
11. Jayachandran G, Sheeladevi N. Sustainability and market orientation of agriculture in Tamil Nadu, India: an analysis of farmers' practices and perceptions. Int J Multidiscip Res. 2025;7(1). https://doi.org/10.36948/ijfmr.2025.v07i01.37278
12. Senthilraja K, Venkatesan S, Udhaya Nandhini D, Dhasarathan M, Prabha B, Boomiraj K, et al. Mitigating methane emission from the rice ecosystem through organic amendments. Agriculture. 2023;13 (5):1037. https://doi.org/10.3390/agriculture13051037
13. Jayachandran G, Sheeladevi N. Sustainable agriculture practices in Tamil Nadu: an analysis of farmers' adoption and perceptions. Int J Multidiscip Res. 2025;7(1). https://doi.org/10.36948/ijfmr.2025.v07i01.37284
14. Bezboruah M, Sharma SK, Laxman ST, Ramesh T, Gulaiya SG, Malathi G, et al. Conservation tillage practices and their role in sustainable farming systems. J Exp Agric Int. 2024;46(9):946-59. https://doi.org/10.9734/jeai/2024/v46i92892
15. Schneider F, Don A, Hennings I, Schmittmann O, Seidel SJ. The effect of deep tillage on crop yield - what do we really know? Soil Tillage Res. 2017;174:193-204. https://doi.org/10.1016/j.still.2017.07.005
16. Rathore SS, Shekhawat K, Babu S, Singh VK. Mitigating moisture stress in Brassica juncea through deficit irrigation scheduling and hydrogel in ustochrepts soils of semi-arid India. Heliyon. 2020;6(12). https://doi.org/10.1016/j.heliyon.2020.e05786
17. Chen CH, Lin KH, Chang YS, Chang YJ. Application of water-saving irrigation and biostimulants on the agronomic performance of maize (*Zea mays*). Process Saf Environ Prot. 2023;177:1377-86. https://doi.org/10.1016/j.psep.2023.08.008
18. Merfield CN. Integrated weed management in organic farming. In: Organic farming. Cambridge: Woodhead Publishing; 2023:31-109. https://doi.org/10.1016/B978-0-323-99145-2.00004-5
19. Rani BS, Chandrika V, Reddy GP, Sudhakar P, Nagamadhuri KV, Sagar GK. Weed dynamics and nutrient uptake of maize as influenced by different weed management practices. Indian J Agric Res. 2022;56(3):283-9.https://doi.org/10.18805/IJARe.A-5500
20. Khan F, Siddique AB, Shabala S, Zhou M, Zhao C. Phosphorus plays key roles in regulating plants' physiological responses to abiotic stresses. Plants. 2023;12:2861. https://doi.org/10.3390/plants12152861

21. Noor H, Ding P, Ren A, Sun M, Gao Z. Effects of nitrogen fertilizer on photosynthetic characteristics and yield. Agronomy. 2023;13 (6):1550. https://doi.org/10.3390/agronomy13061550

22. Xu X, Du X, Wang F, Sha J, Chen Q, Tian G, et al. Effects of potassium levels on plant growth, accumulation and distribution of carbon and nitrate metabolism in apple dwarf rootstock seedlings. Front Plant Sci. 2020;11:904. https://doi.org/10.3389/fpls.2020.00904

23. Mondal S, Saha S, Das SR, Chatterjee D. Impact of conservation agriculture on soil health and environmental sustainability. In: Climate change impacts on soil-plant-atmosphere continuum. Singapore: Springer Nature; 2024:255-81. https://doi.org/10.1007/978-981-99-7935-6_10

24. Sahoo S, Singha C, Govind A, Moghimi A. Review of climate-resilient agriculture for ensuring food security: sustainability opportunities and challenges of India. Environ Sustain Indic. 2024:100544. https://doi.org/10.1016/j.indic.2024.100544

## 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.