RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 60 Issue 11: 1722-1728 (November 2026)

Multivariate Assessment of Soil Quality under Natural and Conventional Farming Systems in Andhra Pradesh, India

D. Bharathi[1], K. Vara Lakshmi[2], Maderametla Roja Rani[3], K. Suresh Kumar[1], Jagadeesh Yeluripati[4]

10.18805/IJARe.A-6617

ABSTRACT

Background: Soil quality is a key indicator of sustainable agricultural productivity and ecosystem health. This study evaluated the effects of natural farming (NF) and conventional farming (CF) on soil physicochemical properties and soil quality across three model mandals of Andhra Pradesh, India.

Methods: Thirty composite soil samples (15 NF and 15 CF) were collected during the 2024-2025 cropping season and analysed for pH, electrical conductivity, bulk density, porosity, soil organic carbon and available nitrogen, phosphorus and potassium. Soil quality index (SQI), fertility index (FI) and nutrient index (NI) were determined using principal component analysis (PCA)-based weighting and standardized scoring methods.

Result: Natural Farming soils exhibited comparatively higher soil organic carbon, lower bulk density and greater porosity than conventional farming soils. Principal component analysis explained 59.3% of the total variance, indicating that soil structural and nutrient attributes were the major contributors to soil quality. Although nutrient availability was comparable between farming systems, Natural farming recorded higher SQI values, indicating improved overall soil quality. These findings demonstrate that natural farming can enhance soil quality while maintaining soil fertility under the agroecological conditions of coastal Andhra Pradesh.

Key words: Conventional farming, Natural farming, Principal component analysis, Soil quality index, Sustainable agriculture.

INTRODUCTION

Soil is a finite and non-renewable resource that underpins agricultural productivity, food security and ecosystem sustainability. Soil degradation in India is a critical agricultural and environmental concern, with approximately 120 million hectares affected by various forms of land degradation (Maji *et al*., 2010). However, prolonged use of nitrogen-intensive fertilizers and continuous conventional farming practices has adversely affected soil health and ecosystem functioning. Globally, approximately one-third of the world's soils are considered moderately to highly degraded due to processes such as nutrient depletion, erosion, salinization, acidification and loss of organic matter (FAO and ITPS, 2015). Soil organic carbon is an important indicator of soil health and plays a key role in maintaining soil structure, nutrient cycling and ecosystem functioning. Intensive tillage, residue removal and inadequate organic matter inputs can contribute to depletion of soil organic carbon (Lal, 2020). Such degradation reduces soil fertility, crop productivity, water-holding capacity and long-term agricultural sustainability. There is a need for sustainable agricultural practices to overcome the impacts of chemically driven agriculture and to restore and maintain ecological balance and improve soil health. Organic and natural farming approaches have gained attention as potential alternatives for promoting sustainable agricultural production and reducing dependence on synthetic agricultural inputs (Singh *et al*., 2022). Natural farming has emerged as one such approach, emphasizing reduced dependence on synthetic agricultural inputs and the use of locally available resources for sustainable crop production (Saxena *et al*., 2022). Among these approaches, zero budget natural farming (ZBNF), introduced by Subhash Palekar, has been promoted as an alternative to input-intensive agricultural practices. ZBNF emphasizes the

[1]Department of Life Sciences (Environment Division), School of Science, GITAM Deemed to be University, Rushikonda, Visakhapatnam-530 045, Andhra Pradesh, India.
[2]Department of Basic Science and Humanities, Vignan Institute of Information Technology (Autonomous) Duvvada, Visakhapatnam-530 049, Andhra Pradesh, India.
[3]Department of Life Sciences (Microbiology and Food Science and Technology), GITAM School of Science, GITAM Deemed to be University, Rushikonda, Visakhapatnam-530 045, Andhra Pradesh, India.
[4]Department of Information and Computational Sciences, The James Hutton Institute, Craigiebuckler, Aberdeen AB15 8QH, Scotland UK.

Corresponding Author: K. Suresh Kumar, Department of Life Sciences (Environment Division), School of Science, GITAM Deemed to be University, Rushikonda, Visakhapatnam-530 045, Andhra Pradesh, India. Email: skolli@gitam.edu

ORCID: https://orcid.org/0000-0003-2425-9714

How to cite this article: Bharathi, D., Lakshmi, K.V., Rani, M.R., Kumar, K.S. and Yeluripati, J. (2026). Multivariate Assessment of Soil Quality under Natural and Conventional Farming Systems in Andhra Pradesh, India. *Indian Journal of Agricultural Research.* **60(11):** 1722-1728. doi: 10.18805/IJARe.A-6617.

Submitted: 25-06-2026 **Accepted:** 05-08-2026 **Online:** 06-10-2026

use of locally available farm resources and reduced dependence on externally purchased synthetic agricultural inputs (Choudhary *et al*., 2023). The Government of Andhra Pradesh has undertaken this initiative in large-scale to promote sustainable and chemical-free agriculture through community-based approach under the flagship program; The Andhra Pradesh community-managed natural farming (APCNF) was launched in 2016 with the support of Rythu Sadhikara Samstha (RySS) (APCNF, 2020). The impact of natural farming on the quality of soil has been the focus of several studies in India. Research comparing ZBNF with conventional farming (CF) has generally shown improvements in soil health indicators. Previous studies have reported improvements in soil quality under Natural Farming systems in Andhra Pradesh, including favourable changes in soil properties (Duddigan *et al*., 2023).

There is a pressing need to generate empirical data on how NF affects soil quality relative to conventional systems. Such evidences are crucial for policymakers, extension agencies and farmers to make adequate decisions on adoption and scaling up of Natural Farming practices. Therefore, the present study aimed to (i) compare selected soil physicochemical properties (bulk density, pH, electrical conductivity, porosity, soil organic carbon and available N, P and K) under natural farming and conventional farming systems; (ii) assess spatial variation in soil quality across the three APCNF model mandals; (iii) compute soil quality index (SQI), fertility index (FI) and nutrient index (NI) and (iv) evaluate soil quality using a principal component analysis (PCA)-based approach.

MATERIALS AND METHODS

The present study was conducted during the 2024-2025 cropping season in three Andhra Pradesh community managed natural farming (APCNF) model mandals located in distinct agroecological regions of Andhra Pradesh, India. Laboratory analyses were carried out in the laboratories of the Department of Life Sciences, Environment Division, GITAM Deemed to be University, Visakhapatnam, Andhra Pradesh, India. The selected mandals comprised Paderu (Alluri Sitharama Raju District), representing a tribal hilly region; Cheedikada (Anakapalli District), representing a semi-arid plain region and Padmanabham (Visakhapatnam District), representing a coastal plain region. The locations of the three study mandals are shown in Fig 1. The geographical coordinates of Paderu, Cheedikada and Padmanabham were 18°03′-18°15′N and 82°30′-82°45′E, 17°45′-17°58′N and 82°50′-83°05′E and 17°50′-18°05′N and 83°20′-83°35′E, respectively. The study area experiences a tropical climate with a mean annual rainfall ranging from 1000 to 1300 mm and the dominant soils are red sandy loams and lateritic soils.

A comparative field sampling approach was adopted to evaluate soil quality under natural farming (NF) and conventional farming (CF) systems. Within each mandal, five NF fields and five CF fields were selected from existing farmers' fields under similar agro-climatic conditions, resulting in a total of 30 composite soil samples (15 NF and 15 CF). After removing surface litter and crop residues, composite soil samples were collected from a depth of 15-30 cm during the 2024-2025 cropping season. Soil sampling was carried out manually using a spade and a digging bar. In each field, soil was collected from nine sampling locations, comprising one central point,

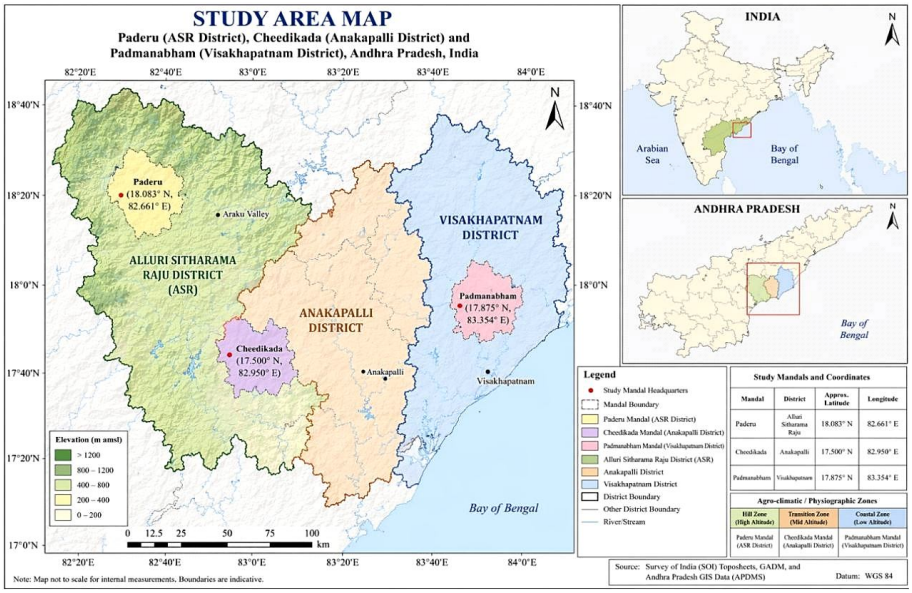


Fig 1: Location of study area.

four corner points and four intermediate points between the centre and the corners. The soil collected from the nine locations was thoroughly mixed on a clean plastic sheet to form a composite sample. The composite sample was reduced by the quartering method, in which the mixed soil was divided into four equal parts, two opposite quarters were discarded and the remaining portions were remixed. The procedure was repeated until the required quantity of representative soil was obtained. The representative sample was then air-dried, gently crushed, passed through a 2-mm sieve and analysed for selected physicochemical properties following standard analytical methods (Jackson, 1973).

The analysed soil parameters included soil pH, electrical conductivity (EC), bulk density (BD), porosity, soil organic carbon (SOC), available nitrogen (N), available phosphorus (P) and available potassium (K). Descriptive statistics (mean, standard deviation and coefficient of variation) were computed for all variables. Differences between natural farming and conventional farming systems were evaluated using independent t-tests, while one-way analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) test was used to compare the three mandals. Statistical significance was considered at $p<0.05$. All statistical analyses were performed using R software (version 4.4.3). Graphical visualizations, including box plots, PCA biplots and correlation heat maps, were generated using the ggplot2 and factoextra packages in R.

Soil quality index

Soil quality index (SQI) was computed using a weighted additive approach. Weights were derived from absolute loading of first principal component (PC1) obtained through PCA and normalized to unity. The SQI was calculated as:

$$SQI = \sum_{i=1}^{n} W_i \times S_i$$

Where,
Si= Normalized score of the i^{th} soil parameter.
Wi= Normalized weight assigned to the i^{th} soil parameter.
n= Number of soil indicators.

$$W_i = \frac{|Li1|}{\sum_{i=1}^{n} |Li1|}$$

Li1= Loading of the i^{th} variable in PC1.
$|Li1|$ = Absolute loading value.
$\Sigma|Li1|$ = Sum of absolute loadings of all variables.

The weights were normalized so that:

$$\Sigma Wi = 1$$

Fertility index (FI)

The fertility index was calculated as the arithmetic mean of standardized fertility indicators.

Where,

$$FI = \frac{\sum_{i=1}^{n} Si}{n}$$

Si= Standardized score of fertility-related parameters.
n= Number of fertility indicators included.

Nutrient index (NI)

$$NI = \frac{(N_L \times 1) + (N_M \times 2) + (N_H \times 3)}{N_T}$$

Where,
N_L= Number of samples in the low category.
N_M= Number of samples in the medium category.
N_H= Number of samples in the high category.
N_T= Total number of samples.

The NI values were interpreted as:
<1.67= Low.
1.67-2.33= Medium.
>2.33= High.

RESULTS AND DISCUSSION

Physicochemical properties NF vs CF

The comparative distribution of soil physicochemical properties under NF and CF systems is presented in Fig 2. Natural farming soils exhibited comparatively higher values for selected soil quality indicators, particularly soil organic carbon and porosity, along with lower bulk density, compared with conventional farming soils, however, these differences were not statistically significant. Electrical conductivity remained within comparable limits in both farming systems, though little variability was observed under CF. Finally, the available macronutrients, including nitrogen (N), phosphorus (P) and potassium (K), generally showed higher median values under NF than under CF, however, the differences were not statistically significant, indicating that Natural Farming maintained nutrient availability at levels comparable to those observed under conventional farming practices. Soil pH tended to be close to neutral under NF, whereas slightly wider variations were observed under CF. Comparatively higher porosity observed under natural farming may indicate more favourable soil aeration and aggregation conditions, potentially associated with organic matter accumulation. Soil organic carbon (SOC) demonstrated comparatively higher median standardized values under NF than under CF, indicating a numerical difference in SOC between two farming systems. The inter quartile ranges and distribution patterns indicate comparatively favourable soil physicochemical conditions under natural farming compared to conventional farming, although the observed differences should be interpreted cautiously where statistical significance was not established.

Soil indices NF vs CF

The normalized density distribution of integrated soil quality metrics revealed statistically significant overall variations between natural farming (NF) and Conventional farming (CF) systems across the study area (Fig 3). The overall

Soil Quality Index (SQI) was significantly higher under NF (mean = 0.539) compared to CF (mean = 0.498; p = 0.0405), demonstrating a positive cumulative impact of natural farming practices on integrated soil health and functional capacity. Similarly, the nutrient index (NI) exhibited a highly significant enhancement under NF (mean = 0.485) relative to CF (mean = 0.393; p = 0.0042), reflecting improved organic matter dynamics and sustainable nutrient retention mechanisms under continuous natural inputs. In contrast, the soil fertility index (FI) demonstrated a slightly higher mean value under CF (0.519) than under NF (0.474), though this difference was not statistically significant (p = 0.556), suggesting that while synthetic fertilizer applications under CF maintain short-term elemental fertility pools, natural farming fosters superior integrated soil physical-chemical quality and long-term soil health functionality.

Spatial variation of soil indices across mandals

Spatial evaluation of soil quality indices across the three study mandals revealed distinct regional variability influenced by both location and management system (Fig 4). In Cheedikada, natural farming (NF) demonstrated higher values for soil quality index (SQI = 0.62) and fertility index (FI = 0.63) compared to conventional farming (CF = 0.56 and 0.47, respectively), while nutrient index (NI) remained comparably high under both systems (CF = 0.80, NF = 0.77). Padmanabham exhibited a similar trend, with NF recording superior SQI (0.49) and FI (0.53) relative to CF (0.43 and 0.44, respectively). Conversely, Paderu recorded slightly lower SQI (0.49) and FI (0.37) under NF compared to CF (0.52 and 0.41, respectively), alongside higher NI under CF (0.70 vs. 0.60). These spatial patterns highlight that while natural farming consistently enhances integrated soil quality and fertility in coastal and

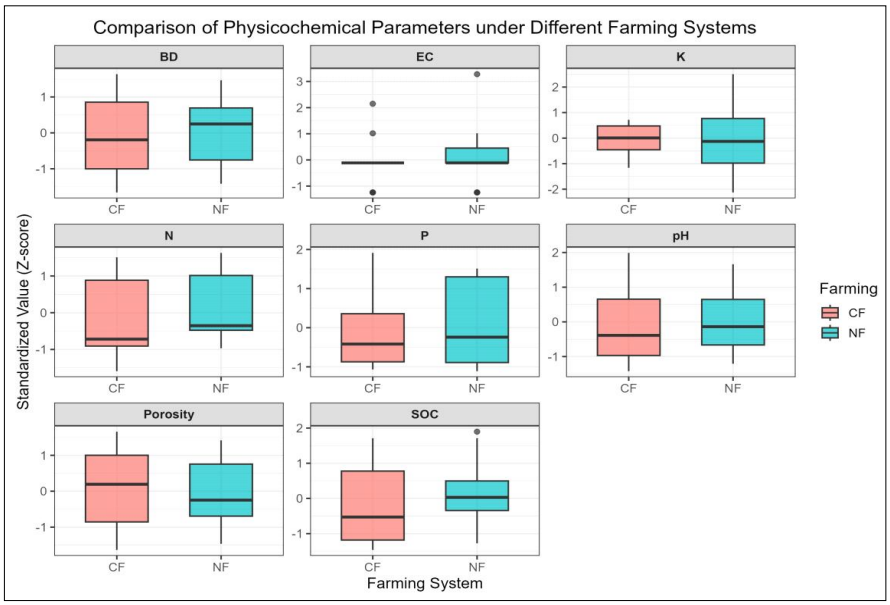


Fig 2: Standardized comparison of soil physical (bulk density and porosity) and chemical (pH, EC, SOC, N, P and K) properties under NF and CF systems.

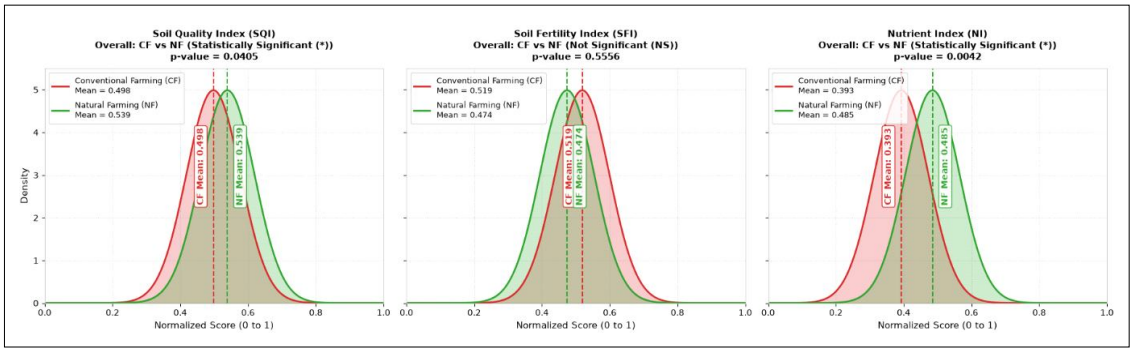


Fig 3: Normalized distribution density of soil quality index (SQI), fertility index (FI) and nutrient index (NI) under natural farming (NF) and conventional farming (CF) systems.

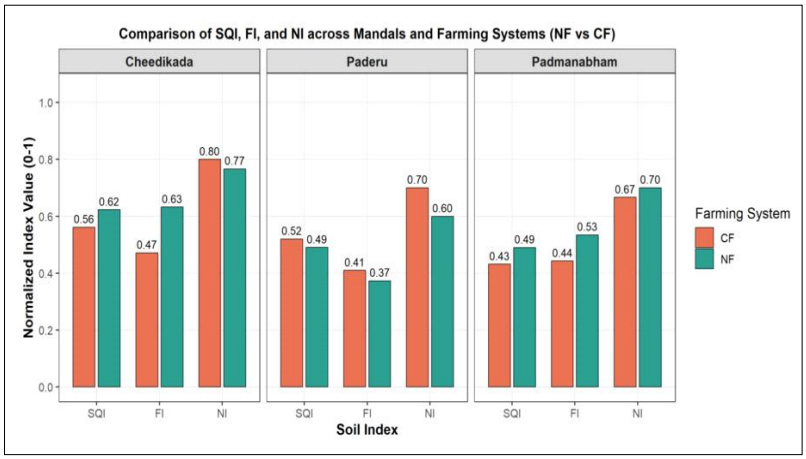


Fig 4: Spatial comparison of soil quality index (SQI), fertility index (FI) and nutrient index (NI) under natural farming (NF) and conventional farming (CF) systems.

plain agroecological zones, local soil characteristics and regional management histories modulate index responses across distinct mandals.

Principal component analysis (PCA)

The PCA biplot illustrating the multivariate distribution of soil physicochemical properties under natural farming and conventional farming systems is presented in Fig 5. The first principal component (PC1) explained 32.3% of total variance, whereas the second principal component (PC2) accounted for 27%, together contributing 59.3% of cumulative variance. PC1 primarily represents soil structural and organic matter influence, as indicated by strong loadings of SOC, bulk density and porosity. PC2 reflects nutrient dynamics, particularly nitrogen and available phosphorus interactions. The clustering of variables indicates coordinated interactions among soil structural and nutrient parameters. Partial overlap between NF and CF systems indicates moderate differentiation in soil characteristics. Bulk density (BD) exhibited strong positive loading along PC1 in the negative PC2 direction, while soil organic carbon (SOC) showed negative loading along PC1, suggesting an inverse relationship between BD and SOC. Available Phosphorus (P) and Potassium (K) were positively associated, as indicated by their alignment along the positive side of PC1, whereas pH and electrical conductivity (EC) showed positive contribution along PC2. Porosity and nitrogen (N) were oriented in a similar direction, indicating positive association between these parameters. The vector orientation indicates correlations among nutrient variables and structural parameters influencing overall soil quality. Overall, the PCA results suggest that soil structural properties (BD, Porosity and SOC) and nutrient parameters (N, P, K) collectively contribute to the variation of farming systems, despite the substantial overlap indicating shared soil characteristics across management practices. The

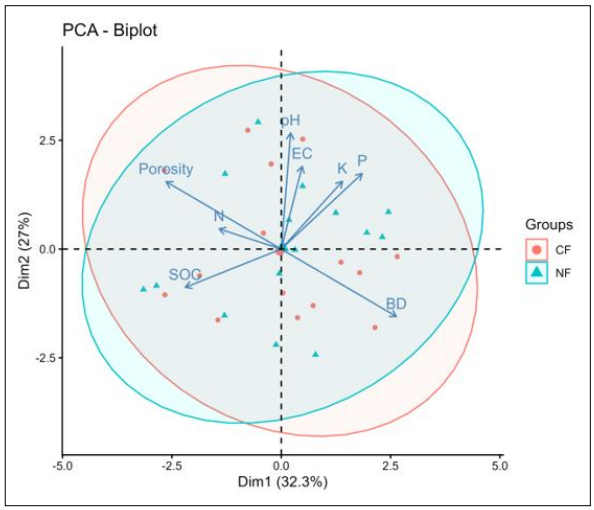


Fig 5: PCA biplot of soil physico-chemical parameters under NF and CF.

negative association between BD and SOC indicates that higher SOC values were associated with lower BD, reflecting a more favourable soil structural condition in the observed dataset.

Correlation analysis

The pearson correlation coefficients among soil physicochemical properties, including pH, electrical conductivity (EC), bulk density (BD), porosity, soil organic carbon (SOC), nitrogen (N), phosphorus (P) and potassium (K) are illustrated in Fig 6. The colour gradient ranges from deep blue (strong positive correlation, r ≈ +1) to deep red (strong negative correlation, r ≈ -1). A strong negative correlation was observed between BD and porosity, indicating an inverse relationship between soil compaction and pore space. In addition, SOC exhibited a negative association with BD and a positive relationship with

porosity and nitrogen (N), indicating associations between soil organic carbon, soil structural properties and nutrient availability. A strong positive correlation between phosphorus (P) and potassium (K), suggesting similar nutrient dynamics or common management inputs. Nitrogen demonstrated moderate association with soil organic carbon, reflecting organic matter nitrogen linkage in soil. Finally, correlation pattern highlights that structural parameters (BD and porosity) and organic carbon are central determinants of soil variability and quality in the study region.

The results illustrate that soil structural properties play an important role in determining soil quality. Previous studies have reported that the addition of organic inputs under Natural Farming systems enhances soil organic carbon and improves nutrient cycling (Ramesh *et al*., 2020). Natural Farming soils exhibited slightly higher mean values of N, P and K, in addition to SOC, although the differences were not statistically significant, suggesting that natural farming (NF) maintains soil fertility comparable to conventional farming (CF). Similar findings have been reported under Andhra Pradesh community managed natural farming (APCNF) systems, where improvements in soil organic carbon, soil aggregation and nutrient retention were observed compared with conventional farming. Chaitanya *et al*. (2022) reported that natural farming fields in Andhra Pradesh exhibited improved physicochemical properties, particularly higher organic carbon. Likewise, Duddigan *et al*. (2023) observed enhanced soil quality and improved crop performance under natural farming systems in South India, attributing these improvements to increased biological activity and continuous organic matter addition. The present findings are consistent with earlier Indian studies reporting improved soil aggregation, organic matter accumulation and nutrient cycling under natural and organic farming systems compared with conventional farming practices.

Several Indian studies have demonstrated that organic and natural farming practices contribute to improved soil health indicators through enhanced microbial activity, reduced soil disturbance and improved nutrient cycling. Bhattacharyya *et al*. (2021) reported that long-term natural and organic farming systems improve soil structural stability, soil organic matter accumulation and nutrient availability compared with chemically intensive farming systems. The present findings are consistent with these observations, particularly the comparatively higher soil quality index (SQI) and improved structural attributes observed under natural farming systems. The strong negative correlation between BD and porosity confirms the inverse relationship between soil compaction and pore space, which directly influences soil aeration, water movement and root growth (Brady and Weil, 2017). Moreover, SOC showed a negative association with BD and a positive relationship with porosity, indicating its relative importance in maintaining soil aggregation and structural stability (Lal, 2004). The comparatively higher SOC observed under natural farming may be associated with the continued application of organic inputs and reduced reliance on synthetic fertilizers. The use of organic fertilizers and organic nutrient sources can contribute to improved soil health and accumulation of soil organic matter (Begum *et al*., 2025; Duddigan *et al*., 2023; Lal, 2004). The observed relationships between SOC, BD and porosity suggest that improved organic matter status may be associated with better soil structural conditions under natural farming. Nitrogen showed a positive association with SOC, indicating a possible relationship between soil organic matter and nutrient retention and mineralization processes (Doran and Parkin, 1994). Phosphorus and potassium were positively correlated, suggesting similar nutrient dynamics under the prevailing management systems (Brejda *et al*., 2000). Overall, these relationships indicate that nutrient availability is closely associated with soil structural condition and organic matter status. PCA explained approximately 59.3% of the total variance, highlighting the combined contribution of structural attributes (SOC, BD and porosity) and nutrient parameters to overall soil variability.

Although complete separation between farming systems was not observed, the multivariate trends suggest that higher organic carbon and lower bulk density were associated with favourable soil quality gradients under Natural Farming. Multivariate approaches such as PCA are effective tools for identifying dominant soil quality indicators (Karlen *et al*., 2001). Long-term studies have reported gradual improvements in soil properties following continued application of organic inputs (Duddigan *et al*., 2023). The clustering of mandals suggests that both soil management practices and inherent site characteristics may contribute to spatial variability. Higher SOC and lower bulk density observed in certain clusters indicate comparatively better soil structural conditions, which may

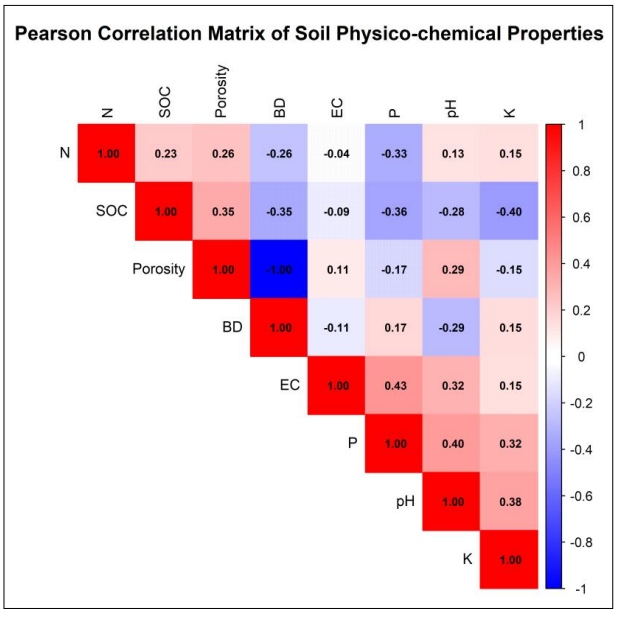


Fig 6: Pearson correlation matrix of soil parameters.

support sustainable soil functionality and crop productivity. However, the present study was limited to a single cropping season and focused primarily on physicochemical soil indicators. Future studies should include observations across multiple cropping seasons, along with biological indicators such as microbial biomass and enzyme activity and crop productivity assessments, to provide a more comprehensive evaluation of the ecological impacts of Natural Farming systems.

CONCLUSION

The present study demonstrated that natural farming (NF) was associated with comparatively better soil structural quality under the selected agroecological regions of Andhra Pradesh. Comparative assessment of soil physicochemical properties revealed relatively higher soil organic carbon (SOC), lower bulk density and higher porosity under NF systems compared with conventional farming (CF). Although CF exhibited marginally higher fertility index (FI) and nutrient index (NI) values, which may reflect differences in nutrient management, NF recorded a comparatively higher soil quality index (SQI), indicating better integrated soil quality under the studied conditions. Multivariate statistical analysis revealed that soil structural parameters, particularly SOC, bulk density and porosity, together with nutrient parameters, contributed substantially to soil variability across farming systems and mandals. Principal component analysis (PCA) explained 59.3% of the total variance, highlighting the combined contribution of soil structural and nutrient-related properties to soil quality assessment.

The observed inverse relationship between bulk density and porosity, along with the positive association between SOC and nutrient availability, emphasizes the importance of organic matter management in maintaining favourable soil conditions. The findings suggest that natural farming practices are associated with improved soil structural properties while maintaining adequate nutrient status under localized agroecological conditions. This study provides empirical evidence supporting the potential of Natural Farming as a sustainable soil management strategy in Andhra Pradesh. However, long-term and multi-seasonal investigations incorporating biological indicators, crop productivity and microbial activity are recommended to provide a more comprehensive understanding of the ecological impacts of natural farming systems.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

APCNF (Andhra Pradesh Community-Managed Natural Farming). (2020). State of the Programme Report. Government of Andhra Pradesh.

Begum, M., Kandali, G.G., Dutta, D. and Bey, C.K. (2025). Organic fertilizer: A key component of organic agriculture-A review. *Agricultural Reviews.* **46(2):** 280-287. doi: 10.18805/ag.R-2626.

Bhattacharyya, R., Das, T.K., Sharma, A.R., Krishnan, P. and Pathak, H. (2021). Soil health indicators under organic, natural and conventional farming systems in India: A review. *Journal of Environmental Managemen*t. **292:** 112804. https://doi.org/10.1016/j.jenvman.2021.112804.

Brady, N.C. and Weil, R.R. (2017). The Nature and Properties of Soils (15th ed.). Pearson Education.

Brejda, J.J., Moorman, T.B., Karlen, D.L. and Dao, T.H. (2000). Identification of regional soil quality factors and indicators. *Soil Science Society of America Journal.* **64(6):** 2115-2124. https://doi.org/10.2136/sssaj2000.6462115x.

Chaitanya, A.K., Prasad, R. and Subrahmanyam, K. (2022). Impact of zero budget natural farming on soil physicochemical properties in Andhra Pradesh, India. *Indian Journal of Agricultural Sciences.* **92(5):** 720-726.

Choudhary, S.K., Kumar, R., Seema. and Kumar, A. (2023). General overview of zero budget natural farming (ZBNF). *Agricultural Reviews.* **44(3):** 328-335. doi: 10.18805/ag.R-2186.

Doran, J.W. and Parkin, T.B. (1994). Defining and Assessing Soil Quality. In: Defining Soil Quality for a Sustainable Environment (SSSA Special Publication No. 35, pp. 3-21). [Doran, J.W., Coleman, D.C., Bezdicek, D.F. and Stewart, B.A. (Eds.)], Soil Science Society of America.

Duddigan, S., Shaw, L.J., Sizmur, T., Gogu, D., Hussain, Z., Jirra, K., Kaliki, H., Sanka, R., Sohail, M., Soma, R., Thallam, V., Vattikuti, H. and Collins, C.D. (2023). Natural farming improves crop yield in SE India when compared to conventional or organic systems by enhancing soil quality. *Agronomy for Sustainable Development.* **43(2):** 31. https://doi.org/10.1007/s13593-023-00884-x.

FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR): Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice-Hall of India Pvt. Ltd., New Delhi, India.

Karlen, D.L. Andrews, S.S. and Doran, J.W. (2001). Soil quality: Current concepts and applications. *Advances in Agronomy.* **74:** 1-40. https://doi.org/10.1016/S0065-2113(01)74029-1.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science.* **304(5677):** 1623-1627. https://doi.org/10.1126/science.1097396.

Lal, R. (2020). The soil-Human Health Nexus. In: Advances in Soil Science. CRC Press. https://doi.org/10.1201/9781003048728.

Maji, A.K., Reddy, G.P.O. and Sarkar, D. (2010). Degraded and Wastelands of India: Status and Spatial Distribution. Indian Council of Agricultural Research, New Delhi.

Ramesh, P., Panwar, N.R., Singh, A.B. and Ramana, S. (2020). Effects of organic and natural farming on soil quality and productivity in India: A meta-analysis. *Soil Use and Management.* **36(4):** 541-554. https://doi.org/10.1111/sum.12600.

Saxena, C.K., Kumar, M. and Singh, R.K. (2022). Zero budget natural farming for sustainable agriculture: A review. *Bhartiya Krishi Anusandhan Patrika.* **37(2):** 105-113. doi: 10.18805/BKAP482.

Singh, M., Rana, R.K., Monga, S. and Singh, R. (2022). Organic and natural farming-A critical review of challenges and prospects. *Bhartiya Krishi Anusandhan Patrika.* **37(4):** 295-305. doi: 10.18805/BKAP569.