*International Journal of Plant & Soil Science*

***Volume 37, Issue 9, Page 510-518, 2025; Article no.IJPSS.143886***
***ISSN: 2320-7035***

# Impact of Various Farming Practices on Soil Physico-Chemical and Biological Properties in Inceptisol

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

***Article Information***

DOI: https://doi.org/10.9734/ijpss/2025/v37i95729

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/143886

***Original Research Article***

***Received: 14/07/2025***
***Published: 10/09/2025***

## ABSTRACT

A field experiment was conducted at College of Agriculture, Pune, during May 2024 to November 2024 on soybean crop with a view to study the soil physico-chemical and biological properties of soil as influenced by different farming practices in Inceptisol. The experiment was laid in Randomized Block Design comprising four replications with five treatments *viz.,*1. Conventional farming practice, 2. Standard package of practices, 3. Organic farming practice, 4. Zero budget natural farming practice and 5. Climate resilient farming.Chemical characteristics of the soil, such

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***Cite as:*** *Kiran Patil, Dharmendrakumar Phalke, Abhay Patil, Sandesh Deshmukh, Deepak Sawale, and Ajinkya Mandake. 2025. "Impact of Various Farming Practices on Soil Physico-Chemical and Biological Properties in Inceptisol". International Journal of Plant & Soil Science 37 (9):510–518. https://doi.org/10.9734/ijpss/2025/v37i95729.*

as pH, EC and calcium carbonate, were unaffected. The soil's available macro and micronutrient content increased as a result of various farming practices. The climate resilient farming practice was shown to have significantly higher levels of available nitrogen (181.40 kg $ha^{-1}$), available phosphorus (26.31 kg $ha^{-1}$), available potassium (474.00 kg $ha^{-1}$), and available sulfur (17.92 mg $kg^{-1}$). In terms of the microbial population, enzymatic activity and available micronutrients, organic farming practice was determined to be beneficial. The availability of micronutrients, including iron (6.47 mg $kg^{-1}$), manganese (3.37 mg $kg^{-1}$), zinc (2.92 mg $kg^{-1}$) and copper (3.61 mg $kg^{-1}$), was greatly impacted by the organic farming method. The addition of organic matter to the soil has improved soil biological health and nutrient cycling, as showed by the significant increases in microbial populations (bacteria, fungi, actinomycetes, Rhizobium, PSB, KMB) and enzymatic activities (alkaline and acid phosphatase, dehydrogenase, urease) after harvest of soybean.

*Keywords: Soybean; farming practices; inceptisol; soil properties; climate resilient farming; organic farming; soil fertility; soil health.*

## 1. INTRODUCTION

Environmental sustainability and food production are key challenges. While the Green Revolution boosted yields, it harmed ecosystems. Traditional Indian agricultural practices offer climate resilience and biodiversity benefits, supporting sustainable food systems and environmental conservation. Soybean (*Glycine max*) often called the “Golden bean” or “Wonder crop,” is a major pulse and oilseed crop known for its high protein (40%) and oil (20%) content. It improves soil fertility through nitrogen fixation and supports successive crops. As a versatile, rich, and affordable source of quality protein and fats, it holds great significance in food and industry. In India the area under soybean cultivation was 13.08 million ha (2022-23) and the production was 12.42 million t. but the productivity still remains low (about 1200-1300 kg $ha^{-1}$) though the crop has potential to harvest 4.0 – 5.0 t $ha^{-1}$. To meet out this increasing demand farmer use fertilizer according to recommended dose or follow their own practice. This can lead to degradation of soil physico-chemical properties lead to non-availability of nutrients to the plant at right time to the plants. It is also known as gold of 20th century due to its easy cultivation, high benefit:cost ratio, less requirement of nitrogen etc. It has atmospheric nitrogen fixing ability and deep root system; thus, soybean cultivation enhances soil health. It contains about 40 per cent protein, 18-20 per cent oil, 26 per cent carbohydrates, 2 per cent phospholipids and 4 per cent minerals (Haldankar et al. 1992).

In India, cereal-based systems dominate but deplete soil, making legume-based cropping, such as soybean in Kharif, a sustainable alternative through nitrogen fixation (Yan et al*.,* 2024). With the global population projected to reach 9.2 billion by 2050, food production must rise 60–70%. However, climate change, with rising temperatures and droughts, threatens productivity. Thus, agriculture must prioritize resilience, eco-efficiency, biodiversity conservation, and smallholder support, aiming for more food with fewer inputs and sustainable livelihood improvement.

By 2050, feeding 9.2 billion people will require a 60–70% increase in food production. Climate change poses serious threats to agriculture, demanding integrated approaches that enhance agro-ecosystem resilience, sustainability, and eco-efficiency. Emphasis must shift toward conserving biodiversity, using fewer inputs, and empowering small farmers through inclusive market access.

## 2. MATERIALS AND METHODS

A field experiment was conducted from May to November 2024 at College of Agriculture, Pune, to evaluate the effects of five farming practices in soybean crop *viz.,* conventional farming ($T_1$), standard package of practices ($T_2$), organic farming practice ($T_3$), zero budget natural farming practice ($T_4$) and climate resilient farming ($T_5$). The study was arranged in a randomized block design with four replications. This experiment on soybean crop was conducted after the harvest of wheat of previous season having same set of treatments. In present investigation for soybean crop, the treatments were superimposed on same layout and randomization. On the same site and same plots, soybean crop was sown using various treatments. The soil nutrient status after harvest of previous wheat crop was used as initial soil nutrient status for this experiment. The

**Table 1. Proximate analysis of organic sources of nutrients**

| Parameters | FYM | Vermicompost | PROM | Jeevamrit | Beejamrit | Ghanajeevamrit |
|---|---|---|---|---|---|---|
| pH | 7.49 | 6.91 | 7.18 | 4.92 | 8.02 | 7.8 |
| EC(dSm$^{-1}$) | 1.66 | 2.12 | 1.74 | 3.22 | 3.11 | 2.7 |
| Total C (%) | 22.26 | 30.79 | 21.06 | 0.22 | 0.13 | 44.54 |
| Total N (%) | 0.69 | 1.48 | 0.78 | 0.32 | 0.16 | 0.97 |
| Total P (%) | 0.39 | 0.79 | 14.57 | 0.09 | 0.11 | 0.49 |
| Total K (%) | 0.38 | 0.81 | 0.37 | 0.59 | 0.48 | 0.99 |
| Total S (%) | 0.61 | 0.45 | 1.12 | - | - | - |
| Fe(mgkg$^{-1}$) | 186 | 35.7 | 12.70 | 7.79 | 18.7 | 228 |
| Mn(mgkg$^{-1}$) | 35.7 | 65.7 | 0.67 | 0.98 | 3.27 | 39.7 |
| Zn(mgkg$^{-1}$) | 14.8 | 18.3 | 2.69 | 0.58 | 12.9 | 14.6 |
| Cu(mgkg$^{-1}$) | 4.39 | 15.2 | 0.46 | 0.51 | 0.49 | 4.49 |
| C:N ratio | 32:1 | 21:1 | 24:1 | 0.7:1 | 0.8 | 45.92 |

conventional treatment involved basal application of chemical fertilizers supplemented with foliar nutrient sprays. Standard and organic treatments combined recommended doses of chemical fertilizers with farmyard manure, biofertilizer seed inoculation and organic amendments. Zero budget natural farming incorporated indigenous inputs such as Ghanjeevamritha, Beejamrit and Jeevamritha, alongside mulching and mixed cropping. Climate resilient farming employed broad bed furrow sowing, balanced chemical fertilization tailored to yield targets, basal application of farmyard manure, biofertilizer seed treatment and mulching coupled with fertilizer application on the basis of STCR approach to optimize resource use efficiency.

To evaluate the effect of different organic and natural farming inputs on soybean performance, a proximate analysis was conducted on a range of soil amendments including farmyard manure (FYM), vermicompost, phosphate-rich organic manure (PROM), Ghanajeevamrit, Jeevamrut, and Beejamrit. The chemical composition of these inputs including macronutrient content, organic carbon, and C: N ratio was analyzed and the results are summarized in Table 1.

## 3. RESULTS AND DISCUSSION

### 3.1 Influence of Farming Practices on Soil Physical Properties

Maximum water holding capacity (MWHC) and bulk density of clay loam soil after soybean harvest were significantly influenced by different farming practices (Table 2). Organic farming practice exhibited the higher MWHC (68.15%), followed by climate resilient farming at 65.86%, while zero budget natural farming showed the lower (61.60%). Enhanced water retention under organic amendments is attributed to improved soil aggregation, porosityand moisture content, consistent with Papini et al. (2011). Bulk density was lower under climate resilient farming (1.23 g cm$^{-3}$) and organic farming (1.26 g cm$^{-3}$), with the higher value observed in conventional farming (1.32 g cm$^{-3}$). Reduced bulk density corresponds probably due to high amount of organic matter and plant roots, pore space, and bio-pores, enhancing soil structure and aeration These results agree with those reported by (Ingle et al., 2024; Sinha et al., 2024; Kuchanwar et al., 2021; Gangwar et al., 2006).

**Table 2. Influence of farming practices on soil physical properties after harvest of soybean**

| Treat. No. | Farming practices | Maximum Water holding capacity (%) | Bulk density (g cm$^{-3}$) |
|---|---|---|---|
| $T_1$ | Conventional farming practice | 62.12 | 1.32 |
| $T_2$ | Standard package of practice | 65.79 | 1.27 |
| $T_3$ | Organic farming practice | 68.15 | 1.26 |
| $T_4$ | Zero budget natural farming practice | 61.60 | 1.30 |
| $T_5$ | Climate resilient farming | 65.86 | 1.23 |
| | **SE(m)±** | **1.64** | **0.02** |
| | **CD (0.05)** | **5.05** | **0.06** |

## 3.2 Influence of Farming Practices on Soil Chemical Properties

Soil pH showed no significant variation among different farming practices, with values ranging from 8.43 standard packages of practices to 8.57 zero budget natural farming practice (Table 3). Organic manure application is known to lower pH in alkaline soils (Mahmood et al., 2017; Yaduvanshi, 2003). Electrical conductivity (EC) was lower under climate resilient farming (0.18 dS $m^{-1}$) and higher in conventional farming (0.25 dS $m^{-1}$), influenced by fertilizer and microbial activity (Aziz et al., 2019). Organic carbon content was significantly higher in organic (0.73%) and climate resilient farming (0.72%) compared to zero budget natural farming (0.52%), reflecting the positive effects of integrated nutrient management (Kundu et al., 2007; Shirale et al., 2014). Calcium carbonate was lower in organic farming (9.35%) and higher in conventional (9.74%), with organic amendments reducing soil $CaCO_3$ $CaCO_3$due to higher organic matter input, enhanced microbial activity, and increased production of organic acids that accelerate carbonate dissolution (Kuchanwar et al., 2021; Ingle et al., 2019; Sleutel et al., 2006). Cation exchange capacity (CEC) was higher under conventional farming (12.43 meq/100g), with combined organic-inorganic treatments enhancing CEC through increased organic matter (Aziz et al., 2019).

## 3.3 Influence of Farming Practices on Soil Available Macronutrients

Post-harvest analysis of soil nutrient status revealed significant differences in available nitrogen (N), phosphorus (P)and potassium (K) among the evaluated farming practices (Table 4). Climate resilient farming ($T_5$) demonstrated superior nutrient availability, recording available nitrogen at 181.40 kg $ha^{-1}$, available phosphorus at 26.31 kg $ha^{-1}$, and available potassium at 474.0 kg $ha^{-1}$, statistically comparable to standard package of practices and organic farming systems. Conversely, zero budget natural farming exhibited significantly lower nutrient concentrations (N: 119.34; P: 8.60; K: 372.16 kg $ha^{-1}$). Enhanced nutrient availability under integrated nutrient management is primarily attributed to increased microbial biomass and activity catalyzing mineralization of organic substrates, coupled with improved soil physical properties such as aggregation and porosity. The synergistic application of organic amendments and inorganic fertilizers optimizes nutrient release, retention, and uptake efficiency. These outcomes corroborate earlier findings on the efficacy of combined nutrient inputs in sustaining soil fertility and crop performance (Nagar et al., 2016; Ingle et al., 2016; Deshmukh et al., 2005; Shah et al., 2022). Implementation of such integrated nutrient management practices is vital for enhancing nutrient cycling and achieving sustainable agro ecosystem productivity.

## 3.4 Influence of Farming Practices on Soil Available Micronutrients

Farming practices significantly influenced soil micronutrient availability after harvest of soybean. Organic farming recorded the higher levels of available iron (6.47 mg $kg^{-1}$), manganese (3.37 mg $kg^{-1}$), zinc (2.92 mg $kg^{-1}$) and copper (3.61 mg $kg^{-1}$) with climate resilient farming and standard package of practices showing comparable but lower values. Zero budget natural farming practice and conventional farming practice exhibited significantly reduced micronutrient availability. The enhanced micronutrient status under organic and integrated systems can be attributed to application of organic manure, which enhance nutrient solubility and improve soil chemical properties, thereby sustaining micronutrient bioavailability (Kamble et al., 2022) research supports the role of micronutrient management, especially Fe, in sustainable crop production on marginal soils. It’s particularly valuable for regions with calcareous or alkaline soils where Fe deficiency limits legume productivity. Also similar (Niharika et al., 2025) findings are valuable for formulating site-specific fertilizer recommendations and improving nutrient management strategies. For further depth, subsequent studies could expand to micronutrients, temporal dynamics, spatial distribution, and direct links to crop performance.

## 3.5 Influence of Farming Practices on Soil Biological Properties

### a) Microbial population

Farming practices significantly affected soil microbial populations after harvest of soybean. Organic farming recorded the higher bacterial

(185.56 × $10^6$ cfu $g^{-1}$), fungal (20.09 × $10^5$ cfu $g^{-1}$), actinomycetes (39.38 × $10^4$ cfu $g^{-1}$), *Rhizobium* (33.30 × $10^6$ cfu $g^{-1}$), phosphate-solubilizing bacteria (29.47 × $10^6$ cfu $g^{-1}$) and potassium-mobilizing bacteria (27.19 × $10^6$ cfu $g^{-1}$), comparable to climate resilient farming and standard package of practices, but significantly higher than conventional farming practice. Enhanced microbial biomass and diversity under organic and integrated nutrient management are attributed to increased soil organic carbon, improved nutrient cyclingand reduced disturbance, promoting soil fertility and sustainability (Sawant et al., 2025 Das and Dkhar, 2011; Gupta et al., 2022).

### b) Soil enzyme activities

Soil enzymatic activities were significantly enhanced by farming practices, with organic farming showing the higher activities of dehydrogenase (13.83 µg TPF $g^{-1}$ $24h^{-1}$), alkaline phosphatase (13.51 µg PNP $g^{-1}$ $2h^{-1}$), acid phosphatase (12.0 µg PNP $g^{-1}$ $2h^{-1}$)and urease (27.33 µg $NH_4^+$-N $g^{-1}$ $day^{-1}$) after soybean harvest. Enhanced enzyme activities under organic management are attributed to improved soil porosity, moisture and microbial activity, which facilitate nutrient cycling and soil health. Phosphatase activity is influenced by moisture and pH, while urease activity benefits from combined organic and inorganic fertilization. These findings align with previous studies highlighting the role of integrated nutrient management in stimulating soil enzymatic functions. The findings are in agreement with those reported by (Sawant et al., 2025; Raiesi and Beheshti, 2015; Marinari et al., 2000; Kumar et al., 2011; Meena et al., 2014; Lakshmi et al., 2011).

**Table 3. Influence of farming practices on soil chemical properties after harvest of soybean**

| Treat. No. | Farming practices | pH | EC (dS $m^{-1}$) | OC (%) | $CaCO_3$ (%) | CEC (meq/100g) |
|---|---|---|---|---|---|---|
| $T_1$ | Conventional farming practice | 8.54 | 0.25 | 0.52 | 9.74 | 12.43 |
| $T_2$ | Standard package of practice | 8.43 | 0.24 | 0.70 | 9.40 | 12.21 |
| $T_3$ | Organic farming practice | 8.46 | 0.24 | 0.73 | 9.35 | 11.61 |
| $T_4$ | Zero budget natural farming practice | 8.57 | 0.20 | 0.52 | 9.62 | 11.13 |
| $T_5$ | Climate resilient farming | 8.45 | 0.18 | 0.72 | 9.48 | 12.13 |
| | **SE(m)±** | **0.04** | **0.02** | **0.02** | **0.11** | **0.20** |
| | **CD (0.05)** | **0.13** | **0.05** | **0.05** | **0.35** | **0.62** |

**Table 4. Influence of farming practices on soil available macronutrients after harvest of soybean**

| Treat. No. | Farming practices | Available Macronutrients (kg $ha^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Fe | Mn | Zn | Cu |
| $T_1$ | Conventional farming practice | 145.33 | 23.48 | 436.62 | 5.36 | 2.92 | 2.40 | 3.42 |
| $T_2$ | Standard package of practice | 177.57 | 24.17 | 447.86 | 5.61 | 2.95 | 2.85 | 3.57 |
| $T_3$ | Organic farming practice | 174.11 | 22.19 | 470.77 | 6.47 | 3.37 | 2.92 | 3.61 |
| $T_4$ | Zero budget natural farming practice | 119.34 | 8.60 | 372.16 | 5.30 | 2.78 | 2.22 | 3.46 |
| $T_5$ | Climate resilient farming | 181.40 | 26.31 | 474.00 | 5.65 | 2.85 | 2.81 | 3.52 |
| | **SE(m)±** | **4.00** | **0.82** | **4.96** | **0.09** | **0.06** | **0.08** | **0.04** |
| | **CD (0.05)** | **12.33** | **2.52** | **15.28** | **0.29** | **0.19** | **0.23** | **0.11** |

**Table 5. Influence of farming practices on microbial population in soil after harvest of soybean**

| Treat. No. | Farming practices | Bacteria ($\times 10^6$cfug$^{-1}$soil) | Fungi ($\times 10^5$cfug$^{-1}$soil) | Actinomycets ($\times 10^4$cfu g$^{-1}$ soil) | *Rhizobium* ($\times 10^6$cfug$^{-1}$ soil) | PSB ($\times 10^6$cfug$^{-1}$soil) | KMB ($\times 10^6$cfug$^{-1}$ soil) |
|---|---|---|---|---|---|---|---|
| $T_1$ | Conventional farming practice | 114.84 | 9.33 | 23.17 | 25.24 | 22.45 | 18.29 |
| $T_2$ | Standard package of practice | 179.62 | 17.25 | 35.46 | 31.38 | 27.90 | 23.45 |
| $T_3$ | Organic farming practice | 185.56 | 20.09 | 39.38 | 33.30 | 29.47 | 27.19 |
| $T_4$ | Zero budget natural farming practice | 174.19 | 15.73 | 34.40 | 30.60 | 25.93 | 21.45 |
| $T_5$ | Climate resilient farming | 183.58 | 16.88 | 39.11 | 30.68 | 28.64 | 24.25 |
|  | **SE(m)±** | **3.20** | **0.50** | **1.63** | **1.20** | **1.18** | **0.91** |
|  | **CD (0.05)** | **9.87** | **1.53** | **5.01** | **3.70** | **3.62** | **2.82** |

**Table 6. Influence of farming practices on enzymatic activities in soil after harvest of soybean**

| Treat. No. | Farming practices | Dehydrogenase (µgTPFg-1soil 24 hr$^{-1}$) | Alkaline phosphatase enzyme (µg PNP g$^{-1}$ 2 hr$^{-1}$) | Acid phosphatase enzyme (µg PNP g$^{-1}$ 2 hr$^{-1}$) | Urease enzyme (µg NH4$^{+}$-N g$^{-1}$ day$^{-1}$) |
|---|---|---|---|---|---|
| $T_1$ | Conventional farming practice | 7.20 | 7.34 | 5.78 | 20.11 |
| $T_2$ | Standard package of practice | 13.31 | 12.87 | 9.85 | 23.39 |
| $T_3$ | Organic farming practice | 13.83 | 13.51 | 12 | 27.33 |
| $T_4$ | Zero budget natural farming practice | 8.34 | 10.15 | 7.31 | 18.19 |
| $T_5$ | Climate resilient farming | 12.94 | 12.00 | 11.66 | 26.48 |
|  | **SE(m)±** | **0.44** | **0.23** | **0.26** | **0.65** |
|  | **CD (0.05)** | **1.36** | **0.70** | **0.79** | **2.01** |

## 4. CONCLUSION

Different farming practices notably affected soil nutrient availability during the short-duration soybean cropping period. Organic and climate-resilient approaches improved soil quality by enhancing microbial activity and enzymatic functions, primarily due to organic inputs like farmyard manure (FYM) and vermicompost. These amendments promoted nutrient mineralization and cycling. Integrated nutrient management, involving both organic and inorganic sources, Integrated nutrient management under climate-resilient and MPKV practices further improved nitrogen, phosphorus, and potassium availability, while organic farming boosted micronutrients like zinc and iron, sustaining soil fertility and productivity.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of manuscripts.

## COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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