Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 01 (JAN-FEB, 2026)
Available online at http://www.agriarticles.com

Conservation Agriculture: A Sustainable Practice for Efficient Nitrogen and Water Management

*Pratiksha Borah[1] and Bharjil Kalita[2]
[1]Department of Soil Science and Agricultural Chemistry, College of Agriculture, Odisha University of Agriculture & Technology (OUAT), Bhubaneswar, Odisha-751003, India
[2]Department of Agronomy, BTC College of Agriculture and Research Station, Bilaspur, Indira Gandhi Krishi Vishwavidyakaya, Raipur, Chhattisgarh-495006, India
*Corresponding Author's email: pratikshaborahpb@gmail.com

Agriculture today stands at a critical crossroads. On one hand, farmers are expected to produce more food to meet the needs of a growing population. On the other hand, they must do so with shrinking natural resources, especially water and soil nutrients, while facing climate variability and rising input costs. Among all nutrients, nitrogen plays the most important role in crop productivity, but it is also the most inefficiently used. Similarly, water scarcity has become a serious limitation to agricultural expansion and stability. In this context, Conservation Agriculture (CA) offers a practical and sustainable solution by improving the efficiency of both nitrogen and water use in farming systems.

What is Conservation Agriculture?

Conservation agriculture is a resource-conserving farming approach built on three core principles: minimum soil disturbance, permanent soil cover, and crop diversification. Instead of frequent ploughing, crops are established using zero or reduced tillage methods. Crop residues are retained on the soil surface rather than being burned or removed, and crop rotations or cover crops are used to diversify the system. These practices help protect the soil from erosion, improve soil structure, and increase biological activity. Over time, conservation agriculture improves soil organic matter and creates a healthier soil environment, which directly affects how nitrogen and water behave in the soil–plant system.

The Close Relationship Between Nitrogen and Water

Nitrogen and water are tightly linked in agricultural soils. Most nitrogen transformations—such as mineralization, nitrification, denitrification, leaching, and plant uptake—are strongly influenced by soil moisture. Excess water can cause nitrate to move beyond the root zone through leaching or be lost as gases through denitrification. On the other hand, insufficient soil moisture limits nitrogen uptake by crops, even when fertilizers are applied in adequate amounts. Conservation agriculture helps maintain a more balanced soil moisture regime. Residue cover reduces evaporation losses and moderates soil temperature, while improved soil aggregation enhances infiltration and water retention. This creates favourable conditions for efficient nitrogen uptake and reduces unnecessary losses.

Effect of Conservation Agriculture on Nitrogen Dynamics

In conventional tillage systems, nitrogen use efficiency is often low. A large fraction of applied nitrogen fertilizer is lost through ammonia volatilization, nitrate leaching, and nitrous oxide emissions, leading to economic losses for farmers and environmental pollution. Globally, it is estimated that nearly half of applied nitrogen is not recovered by crops. Conservation agriculture helps reduce these losses in several ways. Residue retention lowers soil temperature and slows urea hydrolysis, reducing ammonia volatilization. Increased soil organic matter acts as a temporary reservoir for nitrogen, releasing it gradually through mineralization. Minimal soil disturbance also limits rapid nitrogen movement and improves synchronization between nitrogen availability and crop demand. When conservation agriculture is combined with improved nutrient management practices—such as neem-coated urea, precision nitrogen application, and proper placement—nitrogen use efficiency can increase by 15–25% compared to conventional systems. This means farmers can achieve similar or higher yields with less fertilizer input.

Conservation Agriculture and Soil Water Dynamics

Water availability is one of the most critical factors limiting crop productivity, especially in rainfed and semi-arid regions. Conservation agriculture significantly improves soil water dynamics by increasing infiltration and reducing surface runoff. Crop residues on the soil surface act as a mulch, protecting the soil from direct sunlight and wind, thereby reducing evaporation losses. Improved soil structure under conservation agriculture increases the proportion of stable aggregates and favourable pore spaces. This enhances soil water holding capacity and ensures that more water is stored in the root zone for crop use. As a result, crops experience less moisture stress during dry spells. Several studies have shown that conservation agriculture reduces actual evapotranspiration without compromising yield. More water is used for productive transpiration by crops rather than being lost from the soil surface. This leads to improved water use efficiency, where more grain is produced per unit of water consumed.

Water Use Efficiency and Climate Resilience

Improved water use efficiency under conservation agriculture is particularly important in the face of climate change. Erratic rainfall patterns, longer dry spells, and rising temperatures increase the risk of crop failure. Conservation agriculture systems tend to be more resilient because they conserve soil moisture and buffer crops against short-term drought stress. In irrigated systems, conservation agriculture has also been shown to reduce irrigation water requirements. Raised bed planting and residue retention can save substantial amounts of water while maintaining or even increasing crop yields. This is especially valuable in regions facing groundwater depletion and increasing competition for water.

Environmental Benefits of Conservation Agriculture

Beyond improving nitrogen and water use efficiency, conservation agriculture provides several environmental benefits. Reduced nitrate leaching lowers the risk of groundwater contamination, while reduced nitrous oxide emissions help mitigate climate change. Increased soil organic carbon improves soil fertility and contributes to carbon sequestration. By reducing soil erosion and improving soil health, conservation agriculture also supports long-term sustainability of agricultural lands. These benefits extend beyond individual farms and contribute to broader ecosystem services such as water quality protection and climate regulation.

Conclusion

Conservation agriculture represents a shift from intensive soil disturbance to soil stewardship. By improving nitrogen retention, enhancing water availability, and increasing resource use efficiency, conservation agriculture helps farmers achieve stable and sustainable crop production. In a future marked by water scarcity, rising fertilizer costs, and climate uncertainty, conservation agriculture offers a promising pathway toward productive, resilient, and environmentally responsible farming systems.

References

1. Jat, H. S., Jat, R. K., Singh, Y., Parihar, C. M., Jat, S. L., Tetarwal, J. P., ... & Jat, M. L. (2016). Nitrogen management under conservation agriculture in cereal-based systems. Indian Journal of Fertilisers, 12(4), 76-91.

2. Meena, R. K., Vashisth, A., & Das, T. K. (2021). Effect of conservation agriculture on soil hydrothermal regimes, crop evapo-transpiration and water productivity of wheat crop in the semi-arid region of North Western India. Journal of Soil and Water Conservation, 20(4), 424-430.
3. Palm, C., Blanco-Canqui, H., DeClerck, F., Gatere, L., & Grace, P. (2014). Conservation agriculture and ecosystem services: An overview. Agriculture, Ecosystems & Environment, 187, 87-105.
4. Parihar, C. M., Parihar, M. D., Sapkota, T. B., Nanwal, R. K., Singh, A. K., Jat, S. L., ... & Jat, M. L. (2018). Long-term impact of conservation agriculture and diversified maize rotations on carbon pools and stocks, mineral nitrogen fractions and nitrous oxide fluxes in inceptisol of India. Science of the Total Environment, 640, 1382-1392.