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ROOTED IN ECOLOGY, DRIVEN BY ECONOMICS: A REVIEW OF NATURAL FARMING IN GUJARAT'S MAJOR CROP ROTATIONS

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ABSTRACT

Natural farming is increasingly recognized as a sustainable production system that reduces dependence on synthetic inputs while supporting soil health, biodiversity and farm profitability. In India, recent policy support and farmer adoption have accelerated interest in this approach, particularly through the National Mission on Natural Farming, which has been launched as a standalone Centrally Sponsored Scheme with a total outlay of Rs. 2,481 crore and a target to reach 1 crore farmers through 15,000 clusters, 10,000 Bio input Resource Centres and around 2,000 model demonstration farms. Gujarat is among the leading states in this transition, with more than 9.7 lakh farmers reportedly adopting natural farming and large-scale expansion under state support.

This review synthesizes evidence on nutrient management strategies and economic viability of natural farming in major crop rotations, with special emphasis on Gujarat-based systems such as wheat-bajra, maize-groundnut, wheat-maize and oilseed-based rotations. The paper discusses the role of biological nutrient cycling, organic residues, mulching, green manuring, legume integration and local bio inputs in maintaining crop nutrition. It also evaluates the economic implications of reduced external input dependence, cost of cultivation, labor requirements and income stability. Available evidence suggests that natural farming can lower input costs and improve soil health, but its profitability depends strongly on crop choice, rotation design, resource availability and transition management (Sharma *et al*., 2023). The review identifies key research gaps in crop-specific nutrient budgeting, long-term yield stability, sulfur management in oilseeds and region-specific economics under Gujarat's diverse agro-climatic conditions (Kumar *et al*., 2024).

Keywords **:** Natural farming, nutrient management, Economic viability, Crop rotation, Gujarat.

Introduction

Indian agriculture has undergone rapid intensification over the last few decades, with heavy dependence on synthetic fertilizers, pesticides and irrigation to maintain productivity. Although this system has supported food security, it has also led to rising production costs, soil degradation, nutrient imbalance and reduced biological activity in soil. In response, natural farming has gained national importance as an agroecological approach that emphasizes ecological processes, local inputs and low external dependence.

Recent policy support has further strengthened the relevance of this topic. The Government of India launched the National Mission on Natural Farming as a standalone Centrally Sponsored Scheme with a total outlay of Rs. 2,481 crores, aiming to expand natural farming across 15,000 clusters, establish 10,000 Bio input Resource Centres and reach 1 crore farmers. This official institutional backing has effectively transformed natural farming into a major national program rather than a niche, alternative practice (Government of India [GoI], 2024; Singh *et al*., 2022).

Gujarat is particularly important in this context because it has emerged as one of the leading states in natural farming adoption. Government and media reports indicate that more than 9.7 lakh farmers in Gujarat have adopted natural farming and adoption continues to expand with state-level support. Gujarat also has a strong institutional framework for research and training through the Gujarat Natural Farming Science University. For these reasons, a regionalized, Gujarat-focused review of nutrient management and economic viability is both timely and highly relevant to the current agronomic landscape (Patel & Shah, 2023; Government of Gujarat [GoG], 2025).

Agroecological Principles and Mechanisms

Natural farming is a production system that works with ecological processes rather than replacing them with synthetic chemical inputs. It includes practical field interventions such as seed treatment with bio-based formulations, the utilization of cow-derived inputs, mulching, residue retention, minimal soil disturbance and intensive crop diversification. In practice, it systematically overlaps with but is not entirely identical to organic farming or zero-budget natural farming. The foundational objective is to enhance soil biological functioning so that critical nutrient cycling, moisture conservation and long-term plant health are maintained strictly through natural, self-sustaining processes (Verma *et al*., 2021).

The scientific value of this system lies in its precise integration of nutrient supply, soil microbial activity and tailored crop management. Nutrient availability in natural farming is significantly more dependent on organic decomposition, mineralization, biological nitrogen fixation and root-rhizosphere interactions than on direct, synthetic fertilizer applications. Therefore, the ultimate success of the system depends heavily on how effectively an individual farmer manages crop residues, biomass, legume inclusion and structural rotations. This management becomes especially important in semi-arid environments like much of Gujarat, where baseline soil organic matter is historically low and moisture acts as a strict limiting factor (Rathore *et al*., 2022).

Consequently, navigating this transition requires a deep systemic understanding of how biological triggers convert raw organic amendments into plant-available nutrients without inducing critical crop deficiencies. Balancing these slow-release biological processes against immediate crop demands creates unique agronomic trade-offs that directly dictate the farm's macroeconomics. To visually synthesize these multi-layered interactions, the complete pathway connecting farm-level management practices to soil dynamics and ultimate economic outcomes is modeled below (Figure 1).

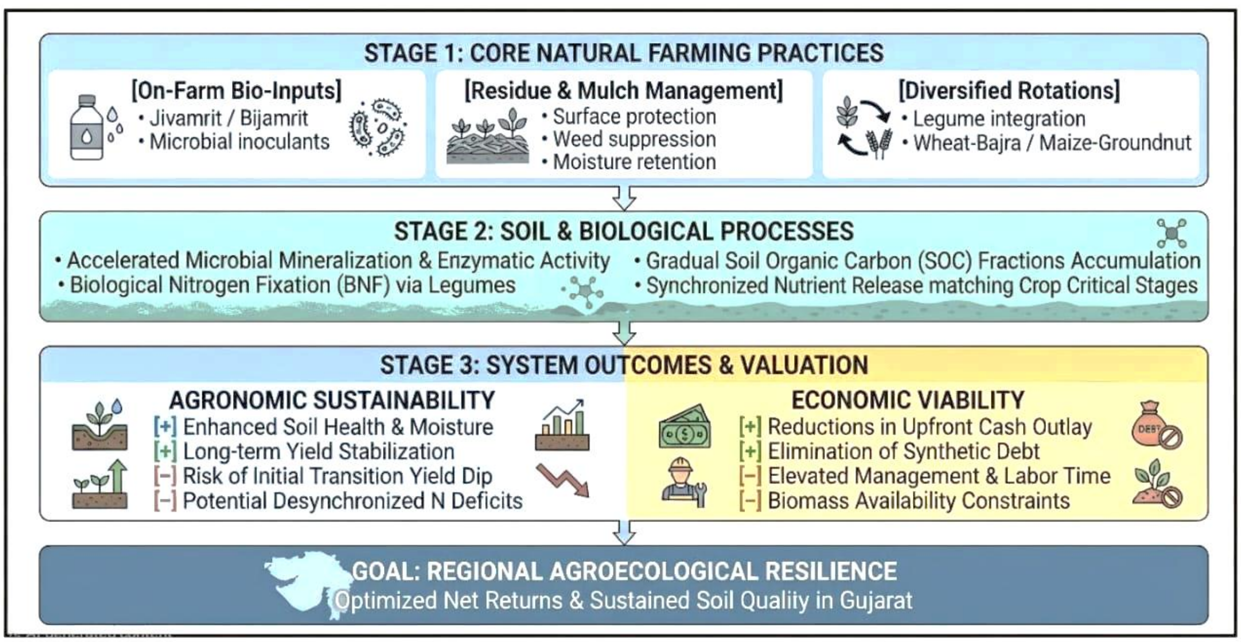

Fig. 1 : Conceptual framework mapping the systemic interactions between on-farm natural farming inputs, soil biological processes and the subsequent agronomic and economic trade-offs within major Gujarat crop rotations.

Nutrient Management in Natural Farming

Nutrient management is central to the overall performance and yields of natural farming systems. Because chemical fertilizers are minimized or completely eliminated, the production system must rely entirely on internal, circular nutrient recycling. This includes the recycling of crop residues, farmyard manure, customized composts, green manures, local bio inputs and biologically active soil management strategies. In many configurations, the subsequent nutrient supply is naturally slower and more closely synchronized with native crop demand, though it may also be less immediately bioavailable than water-soluble synthetic fertilizers (Joshi & Yadav, 2023).

In Gujarat's major crop rotations, baseline nutrient needs vary substantially. Cereals like wheat and maize require relatively high and rapid nitrogen supplies, while millets like bajra are highly tolerant of low input, resource-constrained conditions. On the other hand, oilseeds such as mustard and groundnut demand highly balanced nutrition, requiring adequate levels of sulfur, phosphorus and key micronutrients. Under natural farming, these distinct needs can be partly met through organic manures, legume integration, active residue return and accelerated biological nutrient cycling. However, the system requires meticulous, proactive planning to avoid acute nutrient deficiencies during critical, high-demand crop growth stages (Das *et al*., 2024).

Bio inputs and microbial formulations are frequently promoted within natural farming as supportive toolsets for boosting soil fertility. However, their real-world effectiveness depends heavily on local climate, soil texture, organic biomass availability and farmer management skills. In Gujarat, where hot and dry periods are common throughout the year, the addition of residue mulch and soil cover helps reduce evapotranspiration and significantly improves nutrient retention. This dynamic makes nutrient management functionally inseparable from localized moisture management and soil conservation practices (Choudhary *et al*., 2023).

Crop Rotations in Gujarat

Crop rotation is one of the most critical design features of successful natural farming. Rotations that actively involve cereals, legumes and oilseeds are inherently more resilient than continuous monocropping systems because they diversify systemic nutrient demand and optimize biological cycling pathways. In Gujarat, practical, field-tested rotations include wheat-bajra, wheat-maize, maize-groundnut, soybean-wheat and mustard-based systems. These specific rotations reflect local agro-climatic constraints, historical water availability and regional market preferences.

- **Wheat-Bajra:** Highly important in many drier parts of Gujarat because bajra is drought-tolerant and fits exceptionally well into low input systems.
- **Maize-Groundnut:** Agronomically attractive because the groundnut crop actively contributes nitrogen through biological fixation while improving overall rotational diversity.
- **Oilseed-Based Rotations:** Crucial because Gujarat possesses a major oilseed economy and managing sulfur levels is a critical factor in maintaining quality and yield in mustard and related crops.

A rigorous scientific review must emphasize that crop rotation functions not only as a biological practice but also as a frontline economic and risk-management strategy. The interaction between rotation design and natural farming success is clear. A well-designed rotation improves soil structure, minimizes pest and disease buildup and stabilizes long-term yields while reducing overall fertilizer demand. In contrast, natural farming implemented within continuous, unrotated cereal systems often faces intense nutrient constraints. This is why research must focus on rotation-based nutrient planning rather than assessing natural farming as a single, uniform technology (Patel *et al*., 2024).

Soil Fertility and Biological Functioning

Natural farming adoption is most frequently justified by its potential to systematically restore soil health. Soil health is a multifaceted metric encompassing soil organic carbon (SOC) content, microbial biomass activity, aggregate structural stability, nutrient bioavailability and water-holding capacity. Recent public statements and policy frameworks consistently link natural farming practices directly with long-term soil restoration and improved ecological balance. For Gujarat, this is particularly important because many agricultural soils face chronic challenges from low organic matter and severe moisture stress (Mehta *et al*., 2022; Mishra & Joshi, 2023).

Mulching, residue retention and consistent biomass additions protect the soil surface from solar radiation, mitigate erosion risks and provide energy substrates to support native microbial activity. Over time, these practices accelerate decomposition pathways and organic nutrient release. Legume-based crop rotations further contribute to improved nitrogen availability and enhanced biological diversity within the soil profile. This means natural farming is most effective when it creates ideal physical conditions for soil biology to function optimally.

However, a strong review should not overstate these beneficial effects without scientific qualification. Soil health improvement is usually a gradual, non-linear process and the actual magnitude of change depends on the baseline condition of the field, available biomass resources and the long-term consistency of farmer management. Therefore, literature must present natural farming as a soil-improving strategy with long-term potential rather than a quick, immediate replacement for traditional fertilizer-based management (Swaminathan *et al*., 2023).

Economic Viability

Economic viability is one of the most widely discussed and debated advantages of transitioning to natural farming. The primary economic gain originates from the substantial reduction in purchased synthetic inputs, such as chemical fertilizers, chemical pesticides and sometimes input-associated irrigation costs. Recent regional reports from Gujarat indicate that natural farming has successfully enhanced net farm income primarily by lowering upfront cash input expenditures and breaking chemical dependence. In several official state surveys, farmers practicing natural farming achieved higher net earnings because of lower operational expenditures combined with improved soil resilience.

However, economic viability must be examined with deep academic care. Lower cash input requirements do not automatically guarantee a higher net profit if crop yields experience a sharp decline or if manual labor costs rise significantly. Natural farming often demands significantly more management time and labor for tasks such as crop residue handling, on-farm liquid/solid bio input preparation, mulching and managing diversified crops. Therefore, overall farm profitability must be evaluated using robust metrics like total cost of cultivation, gross returns, net returns and the benefit-cost ratio (BCR), rather than focusing narrowly on input cost reduction alone (Sharma *et al*., 2024).

For Gujarat, specific crop choice strongly dictates economics. Rotations utilizing bajra, groundnut, soybean and mustard are frequently better suited to low input ecology and maintain better profit margins than highly nutrient-demanding, continuous cereal systems. In addition, a farmer's direct access to livestock resources (such as indigenous cattle) and local biomass strongly improves the internal economics of natural farming. The article should therefore present economic viability as highly conditional and context-dependent, rather than a universal certainty (Reddy *et al*., 2023).

Gujarat Adoption and Policy Context

Gujarat currently offers one of the strongest and most definitive regional cases for natural farming implementation across India. According to recent data, more than 9.7 lakh farmers across the state have adopted natural farming, with the system being actively associated with improved soil health parameters and a reduced reliance on external inputs. Another comprehensive state report noted that Gujarat had approximately 5.64 lakh farmers practicing natural farming on 2 lakh hectares during the 2024-25 agricultural cycle. These numbers indicate rapid geographic expansion and strong policy visibility (The Print, 2025; The Week, 2025).

The institutional framework supporting this transition is also highly favorable. The establishment of the Gujarat Natural Farming Science University provides a dedicated, specialized platform for academic research, extension training and location-specific technology development. This institutional backing makes the state uniquely suitable for hosting long-term agronomic experiments, farmer-participatory action research and site-specific nutrient budgeting studies. In a review context, Gujarat serves as both an adoption leader and a premier research opportunity for agroecological science (GoG, 2024).

Furthermore, policy support from the National Mission on Natural Farming strengthens the study's relevance. The massive national scale of the mission suggests that natural farming will continue to expand systematically through formalized clusters, Bio input Resource Centres and model demonstration farms. Consequently, evidence generated from Gujarat-based farming systems may directly influence national implementation models and policy updates moving forward (Gov of India [GoI], 2024).

Constraints and Challenges

Despite overwhelmingly positive policy reports, natural farming faces several critical limitations and implementation bottlenecks.

- **Transition Risk:** Yields can fluctuate significantly or decline when fields are shifted from conventional, synthetic fertilizer-dependent systems to low input ecological systems before soil biological activity is fully restored.
- **Nutrient Desynchronization:** The rate of nutrient release from organic and biological sources does not always match peak crop demand stages, a constraint that is particularly visible in high-yielding cereal crops.
- **Biomass Scarcity:** Organic biomass availability may be heavily limited in arid and semi-arid zones, which directly reduces the feasibility and effectiveness of widespread mulching and internal nutrient supply.
- **Data Limitations:** There is a pronounced shortage of rigorous, long-term, crop-specific field data from controlled experiments within Gujarat. Many

current publications are policy summaries, institutional brochures, or broad adoption statistics rather than peer-reviewed agronomic experiments.

There is a vital need for comprehensive economic analyses that accurately factor in family labor burdens, transition risks and local market behavior. To ensure this review remains scientifically objective and well-balanced, these specific operational constraints must be highlighted alongside the benefits (NITI Aayog, 2026).

Research Gaps

Several critical research gaps deserve prominent emphasis in this review to guide future academic inquiries:

- **Long-Term Agronomic Trials:** Long-term, multi-year experiments are strictly required to precisely measure temporal changes in soil organic carbon pools, microbial biomass, actual nutrient bioavailability and yield stability under diverse Gujarat conditions.
- **Crop-Specific Nutrient Budgeting:** Comprehensive nutrient input-output balance sheets must be scientifically modeled for major regional crops including wheat, bajra, maize, groundnut, soybean and mustard.
- **Sulfur Management in Oilseeds:** Special attention must be paid to sulfur dynamics within oilseed-based rotations, as sulfur deficiency under strict natural farming can drastically reduce seed oil content and final market yields.
- **Comparative System Studies:** Direct side-by-side comparative trials should examine natural farming against conventional chemical systems and integrated nutrient management (INM) systems under identical agro-climatic conditions.
- **Farm-Level Economic Modeling:**Microeconomic studies are required to quantify hidden labor burdens, gender-disaggregated labor requirements, farm-level risk reduction and multi-year profitability trajectories (Sharma *et al*., 2024; Kumar *et al*., 2024).

Conclusion

Natural farming has successfully transitioned into a core agricultural strategy across India, with Gujarat serving as a leading state in both widespread adoption and institutional policy support. Synthesized evidence indicates that natural farming can significantly reduce production costs, improve soil health indices and support stable farmer incomes, provided it is closely integrated with suitable crop rotations and sound biological management. At the same time, its ultimate success depends heavily on crop choice, proactive nutrient budgeting, local biomass availability and effective management of the transition phase (Sharma *et al*., 2023).

For Gujarat, the most promising and resilient future lies in rotation-based natural farming systems that intentionally combine cereals, climate-resilient millets, nitrogen-fixing legumes and high-value oilseeds. Such systems optimize internal nutrient cycling and economic resilience while responding effectively to localized agro-climatic conditions. A comprehensive review article addressing these specific dynamics provides a meaningful, timely contribution to sustainable agriculture research and future policy design.

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