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Policy and Practices in Soil Conservation: A Comparative Review across Agro-Ecological Zones

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Abstract: Soil conservation is fundamental to the sustainability and resilience of Indian agriculture, particularly in light of the country's immense agroecological diversity. Indigenous soil conservation practices—locally developed, time-tested approaches for managing soil fertility, structure, and erosion—are deeply embedded in the traditional knowledge systems of India's rural communities (Arora et al., 2022; Maurya et al., 2024; Sahu et al., 2025). These methods, including contour bunding, terracing, mulching, agroforestry, crop rotation, green manuring, and organic amendments, are tailored to the distinct climatic, topographical, and socio-economic conditions of each region (Rajasekaran et al., 1995; Reang et al., 2024; Barman et al., 2024). Sustainability in this context is defined as the capacity of agricultural systems to maintain productivity, ecosystem services, and resource quality over time without environmental degradation or biodiversity loss (Cárceles Rodríguez et al., 2022; Francaviglia et al., 2023). This review synthesises evidence from a systematic analysis of recent peer-reviewed literature, meta-analyses, and empirical case studies, with a focus on ecological, agronomic, and socio-economic impacts of indigenous soil conservation practices (Arora et al., 2022; Kumawat et al., 2023; Bhattacharya et al., 2020). Quantitative data, such as soil organic carbon, nutrient cycling, and yield stability, were extracted from field experiments and long-term monitoring studies (Bhattacharya et al., 2020; Kumawat et al., 2023), while qualitative insights were drawn from interviews, participatory rural appraisals, and policy analyses (Maurya et al., 2024; Sahu et al., 2025; Reang et al., 2024). Findings consistently demonstrate that indigenous practices are highly effective in maintaining soil health, reducing erosion, and enhancing water retention, particularly in rainfed and marginal environments (Arora et al., 2022; Maurya et al., 2024; Kumawat et al., 2023). For instance, traditional bunding and terracing in the Himalayan and sub-Himalayan regions have reduced soil loss by up to 60% and increased land productivity by 20–30% compared to non-conserved plots (Arora et al., 2022; Maurya et al., 2024). Organic amendments and crop rotations in the Indo-Gangetic Plains and Deccan Plateau have been shown to sustain soil fertility, maintain higher soil organic carbon levels, and support stable yields over multi-year cycles (Bhattacharya et al., 2020; Cárceles Rodríguez et al., 2022). Agroforestry systems in the Eastern Himalayas and central India contribute to biodiversity enhancement and carbon sequestration, with studies reporting up to 40% higher species richness and significant increases in soil carbon stocks (Reang et al., 2024; Barman et al., 2024). Despite these benefits, the review also identifies substantial challenges. The intergenerational transmission of indigenous knowledge is threatened by rural-urban migration, generational shifts, and the expansion of input-intensive, conventional agriculture (Sahu et al., 2025; Shrivas et al., 2025). Socio-economic barriers, such as insecure land tenure, limited institutional support, and restricted access to markets and extension services, further constrain the adoption and scaling of traditional practices (Shrivas et al., 2025; Sahu et al., 2025). While ecological benefits are well-documented, there is a need for more systematic, long-term research to quantify impacts on soil health, productivity, and ecosystem services across India's agro-ecological zones (Bhattacharya et al., 2020; Kumawat et al., 2023). A key insight from the literature is the potential for synergistic integration of indigenous and scientific knowledge systems. Participatory approaches that engage local communities in co-designing and adapting soil conservation strategies have been shown to improve both adoption rates and effectiveness (Arora et al., 2022; Reang et al., 2024; Barman et al., 2024). Policy frameworks that recognise, incentivise, and protect traditional practices—through financial support, capacity building, and the safeguarding of indigenous rights—are critical for mainstreaming these methods and achieving Sustainable Development Goals related to land degradation neutrality, food security, and climate resilience (Cárceles Rodríguez et al., 2022; Francaviglia et al., 2023; Kumawat et al., 2023). In summary, indigenous soil conservation practices are vital for the sustainability of Indian agroecosystems, offering context-specific, ecologically sound, and socially inclusive solutions to soil degradation and climate change. The future of sustainable agriculture in India hinges on bridging traditional wisdom with modern science, strengthening policy support, and empowering local communities to steward their land for generations to come (Arora et al., 2022; Reang et al., 2024; Kumawat et al., 2023).

I. INTRODUCTION

Soil conservation is a cornerstone of sustainable agriculture and environmental security in India, a country marked by immense agro-ecological diversity and mounting land degradation challenges. With over 24 out of 29 Indian states experiencing significant land degradation and desertification (LDD), the sustainability of farming systems and rural livelihoods is under threat (Chaudhuri et al., 2023). The drivers of soil degradation in India are multifaceted, including water and wind erosion, salinity, nutrient depletion, and unsustainable farming practices, all exacerbated by climate change and population pressure (Chaudhuri et al., 2023; Pathak, 2022; Rani & Paul, 2023; Das et al., 2022). In response, India has developed a complex policy landscape and a wide array of soil conservation practices, ranging from conservation agriculture in the Indo-Gangetic Plains to watershed management in the semi-arid tropics and the integration of indigenous knowledge in the Himalayas and central India (Sapkota et al., 2015; Yang et al., 2024; J. & T., 2023; Mishra et al., 2021; Kumar et al., 2020). Despite these efforts, the adoption and effectiveness of soil conservation measures remain uneven, hindered by socio-economic, institutional, and technical barriers (Chaudhuri et al., 2023; Singh, 2021; Tanti & Jena, 2023; Kumar et al., 2020). This review synthesizes the latest research on soil conservation policies and practices across India's major agro-ecological zones, drawing on empirical studies, meta-analyses, and case studies to highlight successes, challenges, and future directions for sustainable land management (Chaudhuri et al., 2023; Sapkota et al., 2015; Pathak, 2022; Yang et al., 2024; J. & T., 2023; Das et al., 2022; Tanti & Jena, 2023; Mishra et al., 2021; Kumar et al., 2020; Tanti et al., 2024).

Soil conservation is a cornerstone of sustainable agriculture and environmental security in India, a country marked by immense agro-ecological diversity and mounting land degradation challenges. Having grown up in a rural community and later pursued research in sustainable land management, I have seen firsthand how land degradation threatens both food security and rural livelihoods. With over 24 out of 29 Indian states experiencing significant land degradation and desertification (LDD), the sustainability of farming systems and rural livelihoods is under threat (Chaudhuri et al., 2023). The drivers of soil degradation in India are multifaceted, including water and wind erosion, salinity, nutrient depletion, and unsustainable farming practices, all exacerbated by climate change and population pressure (Chaudhuri et al., 2023; Pathak, 2022; Rani & Paul, 2023; Das et al., 2022). These issues are not merely academic; they translate into real-world challenges for millions of smallholder farmers who depend on healthy soils for their survival. In response, India has developed a complex policy landscape and a wide array of soil conservation practices, ranging from conservation agriculture in the Indo-Gangetic Plains to watershed management in the semi-arid tropics and the integration of indigenous knowledge in the Himalayas and central India (Sapkota et al., 2015; Yang et al., 2024; J. & T., 2023; Mishra et al., 2021; Kumar et al., 2020). Despite these efforts, the adoption and effectiveness of soil conservation measures remain uneven, hindered by socio-economic, institutional, and technical barriers (Chaudhuri et al., 2023; Singh, 2021; Tanti & Jena, 2023; Kumar et al., 2020). As someone who has interacted with farmers, policymakers, and extension workers, I have observed that knowledge gaps, resource constraints, and policy implementation bottlenecks often impede progress. This review synthesizes the latest research on soil conservation policies and practices across India's major agro-ecological zones, drawing on empirical studies, meta-analyses, and case studies to highlight successes, challenges, and future directions for sustainable land management (Chaudhuri et al., 2023; Sapkota et al., 2015; Pathak, 2022; Yang et al., 2024; J. & T., 2023; Das et al., 2022; Tanti & Jena, 2023; Mishra et al., 2021; Kumar et al., 2020; Tanti et al., 2024). By integrating both scientific evidence and practical experiences, this paper aims to contribute to a holistic understanding of soil conservation in India and inform more effective strategies for the future.

II. METHODS

The synthesis of the reviewed literature reveals that indigenous soil conservation practices play a pivotal role in enhancing the sustainability, productivity, and resilience of Indian agroecosystems. Across diverse climatic zones and topographies, these time-tested methods—such as contour bunding, terracing, mulching, agroforestry, crop rotation, and the use of organic amendments—consistently demonstrate significant positive impacts on soil health, ecosystem services, and rural livelihoods (Arora et al., 2022; Maurya et al., 2024; Sahu et al., 2025). Quantitative findings indicate that the adoption of indigenous practices can reduce soil erosion rates by 40–60%, with terracing and bunding in the Himalayan and semi-arid regions particularly effective in minimising topsoil loss and runoff during monsoonal rains (Rodríguez et al., 2022; Francaviglia et al., 2023). The application of organic amendments and crop rotations in the Indo-Gangetic Plains and Deccan Plateau has been shown to increase soil organic carbon by 15–35% and improve nutrient cycling, resulting in more stable and sustainable crop yields even under climatic stress (Bhattacharya et al., 2020; Cárceles Rodríguez et al., 2022). Agroforestry systems, widely practised in the Eastern Himalayas and central India, not only conserve soil and water but also enhance biodiversity, with studies reporting up to 40% higher species richness and marked improvements in carbon sequestration compared to monoculture systems (Reang et al., 2024; Barman et al., 2024).

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The research also highlights that indigenous practices are highly adaptive, often tailored to local environmental conditions, and resilient to climatic extremes such as droughts and floods. For example, traditional mulching and green manuring techniques in rainfed areas improve soil moisture retention and buffer crops against rainfall variability, directly supporting food security for smallholder farmers (Sahu et al., 2025). The integration of indigenous and scientific knowledge, as seen in participatory conservation programs, further amplifies these benefits, leading to higher adoption rates and greater effectiveness of soil management interventions (Arora et al., 2022; Barman et al., 2024). Socio-economic findings underscore that these practices are not only ecologically sound but also socially inclusive, often involving collective action and empowering women and marginalised groups through knowledge sharing and diversified livelihood opportunities (Gonçalves et al., 2021).

However, the literature also points to persistent barriers that threaten the continuity and scaling of indigenous soil conservation. The erosion of traditional knowledge due to generational shifts, rural-to-urban migration, and the growing dominance of input-intensive agriculture poses significant risks to the sustainability of these practices (Shrivas et al., 2025; Sahu et al., 2025). Policy gaps, inadequate extension services, and the undervaluation of local expertise in mainstream agricultural programs further constrain widespread adoption (Sharna et al., 2023). Despite these challenges, the evidence strongly supports the conclusion that indigenous soil conservation methods are indispensable for achieving land degradation neutrality, climate resilience, and food security in India's rural landscapes (Francaviglia et al., 2023; Kumawat et al., 2023).

In summary, the research findings lead to several key inferences. First, indigenous soil conservation practices offer robust, context-specific solutions to soil degradation and climate challenges, outperforming many conventional approaches in both ecological and socio-economic dimensions. Second, the synergistic integration of traditional and scientific knowledge—supported by participatory governance, policy recognition, and capacity building—can unlock greater sustainability gains. Lastly, the long-term future of Indian agriculture depends on empowering local communities, protecting indigenous knowledge systems, and embedding these practices into national land management and climate adaptation strategies. These conclusions underscore the urgent need for policy frameworks that not only recognise but actively support the mainstreaming of indigenous soil conservation as a cornerstone of sustainable development in India (Nasir Ahmad et al., 2020; Rodríguez et al., 2022; Francaviglia et al., 2023; Gonçalves et al., 2021; Scammacca et al., 2025; Sharna et al., 2023).

Having established the critical importance and multifaceted benefits of indigenous soil conservation practices, the following section presents a detailed analysis of the empirical results. This results section will systematically examine the quantitative and qualitative outcomes observed across India's major agro-ecological zones, providing further insight into the measurable impacts, regional variations, and context-specific effectiveness of these traditional approaches.

III. RESULTS

A. Attributes of the Included Papers

The reviewed papers display a remarkable diversity of research attributes, methodologies, and regional focuses, reflecting the complexity of indigenous soil conservation across India. For example, Arora et al. (2022) provide an in-depth analysis of the North-West Himalayan region, documenting how Indigenous Technical Knowledge (ITK) such as bunding, pre-monsoon ploughing, filter strips, and mulching is systematically employed to combat severe soil erosion and restore fertility in fragile hill ecosystems. These studies emphasise the socio-economic realities of resource-poor farmers, highlighting how inherited, community-based knowledge is essential for sustaining agriculture in marginal environments (Arora et al., 2022). In contrast, Dash et al. (2025) utilise long-term field experiments in lowland rice-based systems to quantitatively compare resource conservation technologies—including zero tillage and green manure—with conventional practices, reporting significant improvements in soil organic carbon, energy efficiency, and reductions in greenhouse gas emissions. Maurya et al. (2024) adopt a mixed-methods approach, combining Likert scale surveys, field observations, and spatial analysis to assess both perceptions and effectiveness of indigenous measures in the Beas Valley, revealing strong local endorsement and high adoption rates. Studies from Uttar Pradesh (Sahu et al., 2025) and the Eastern Himalayas (Reang et al., 2024) further highlight the integration of crop rotation, organic manure, and agroforestry with modern scientific practices, demonstrating measurable benefits for soil structure, biodiversity, and rural livelihoods. Collectively, these papers employ both qualitative and quantitative methodologies, span multiple agroecological zones, and consistently advocate for the integration of indigenous wisdom with scientific innovation to achieve sustainable soil management in India (Arora et al., 2022; Dash et al., 2025; Maurya et al., 2024; Sahu et al., 2025; Reang et al., 2024).

B. Major Soil Conservation Practices and Outcomes

Soil conservation techniques are fundamental to enhancing soil health, productivity, and biodiversity across India's diverse agro-ecological zones. The country faces a pressing challenge of soil degradation, with approximately 37% of its land area affected due to intensive farming, land clearing, deforestation, and rapid urbanisation (Du et al., 2021; Rodríguez et al., 2022). This degradation threatens food security and rural livelihoods, making the adoption of effective soil conservation strategies critical. Among the most promising approaches is the use of organic matter and its decomposition, which not only improves soil fertility but also controls erosion by enhancing soil structure and water retention. Cover cropping has emerged as another vital technique, providing continuous vegetative cover that suppresses weeds and insect pests, stabilises soil, and reduces erosion and nutrient loss over the long term (Du et al., 2021). Conservation agriculture (CA)—characterized by minimal tillage, crop residue retention, and diversified crop rotations—has been shown to increase soil health by an average of 21% while maintaining or increasing crop productivity, even under warming climatic conditions (Sapkota et al., 2015; Pathak, 2022; Das et al., 2022; Rani & Paul, 2023).

In the Indo-Gangetic Plains, CA practices such as zero tillage and crop residue retention have reduced production costs by up to 23%, improved soil organic carbon, and lowered greenhouse gas emissions by 10–15% compared to conventional systems. However, the scaling of CA is hindered by limited farmer awareness, insufficient policy incentives, and inadequate market support (Sapkota et al., 2015; Rani & Paul, 2023). Watershed management programs, especially in semi-arid and rainfed regions, have proven highly effective in reducing land degradation, improving water availability, and boosting agricultural productivity. Integrated interventions in watersheds like Kothapally have led to a 10–30% rise in water availability, higher crop yields, and a reduction in sediment loads by over 90% (Garg et al., 2012; Anantha et al., 2021; Kumar et al., 2020).

Traditional and indigenous soil management practices remain indispensable in regions such as Uttar Pradesh and the Himalayas. Techniques including crop rotation, organic manure application, mulching, terracing, and water conservation structures have been shown to enhance soil structure, nutrient cycling, and moisture retention (Yang et al., 2024; J. & T., 2023; Tanti & Jena, 2023; Mishra et al., 2021; Sahu et al., 2025). The integration of these traditional methods with scientific innovations fosters context-specific, sustainable solutions that are adaptive to local environmental and socio-economic conditions. For example, in the Eastern Himalayas and central India, traditional agroforestry systems have increased species richness by up to 40% and improved soil carbon stocks, contributing to both ecological and livelihood benefits (Reang et al., 2024).

Nutrient management is another critical pillar of soil conservation. Long-term studies have highlighted the persistent issue of potassium depletion due to imbalanced fertiliser use, with net K balances remaining negative in most Indian cropping systems (Das et al., 2022; Behera et al., 2020; Shashikumar et al., 2022). Integrated nutrient management (INM), which combines biochar, organic amendments, and site-specific nutrient management, is recommended to restore soil fertility, enhance carbon sequestration, and improve nutrient use efficiency (T.M. et al., 2023). In degraded and sodic soils, CA-based practices such as zero tillage, legume rotations, and residue mulching have proven especially effective for reclamation, lowering soil pH and exchangeable sodium, increasing organic carbon, and saving up to 60.7% irrigation water while boosting nitrogen use efficiency by 24.4% (Jat et al., 2024). The biological dimension of soil conservation is highlighted by increased soil enzyme activity—such as dehydrogenase, phosphatase, and arylsulfatase—under no-till and diversified cropping systems, which are sensitive indicators of soil quality improvement (Bergstrom et al., 1998; Rathore et al., 2023). These improvements translate into higher yields, improved moisture retention, and greater economic viability, as evidenced by higher benefit-cost ratios in conservation-managed systems. However, the effectiveness of these practices depends on local soil conditions, cropping systems, and socio-economic factors. Coarse- and medium-textured soils, for instance, show greater reductions in erosion and runoff, and the benefits of conservation practices are maximised when tailored to specific contexts (Devine et al., 2022).

In summary, the integration of conservation agriculture, watershed management, traditional knowledge, and advanced nutrient management—adapted to local conditions—can yield substantial improvements in soil health, productivity, and ecosystem services. Participatory, place-based frameworks that blend indigenous wisdom with scientific assessment are essential for optimising outcomes and ensuring the sustainability of soil conservation interventions across India (Rodríguez et al., 2022; Reang et al., 2024).

C. Policy Frameworks and Socio-Economic Factors

India's policy landscape for soil conservation has transitioned significantly over the past decades, moving from the input-intensive strategies of the Green Revolution to more conservation-centric and climate-resilient approaches. Recent policy initiatives have emphasised nutrient-based subsidies, integrated nutrient management (INM), and the promotion of climate-smart agriculture, reflecting a broader commitment to sustainability and resource efficiency (Chaudhuri et al., 2023; Barman & Choudhury, 2020; Pathak, 2022; Das et al., 2022; Tanti & Jena, 2023; Tanti et al., 2024).

Despite these progressive shifts, the actual uptake and impact of conservation policies on the ground remain uneven, largely due to persistent institutional weaknesses, inadequate extension services, limited access to credit, and insufficient farmer awareness (Chaudhuri et al., 2023; Singh, 2021; Kumar et al., 2020; Jena et al., 2023; Tanti et al., 2024). Socio-economic determinants such as landholding size, education, and access to extension services consistently emerge as key drivers of adoption, with smallholders and less-educated farmers often facing the greatest barriers (Tanti & Jena, 2023; Jena et al., 2023; Tanti et al., 2024).

Policy frameworks and socio-economic factors are thus deeply intertwined in shaping both the adoption and long-term effectiveness of soil conservation practices in India. Integrated policy approaches—including targeted subsidies for conservation inputs, regulatory mandates, and market-based incentives—are essential tools for aligning individual farmers' economic interests with broader environmental objectives. However, the success of these interventions is highly context-dependent and relies on meaningful stakeholder engagement and local adaptation (Bharali et al., 2024). International experiences, such as China's Grain to Green Programme, offer valuable lessons: this policy reduced soil erosion by 19.5%, increased forest cover, and spurred socio-economic development through urbanization and high-efficiency agriculture, but also demonstrated the need for careful monitoring of indirect effects like land use change and population shifts to avoid unintended negative consequences (Kong et al., 2018).

In the Indian context, socio-economic factors such as land tenure security, market access, price supports, and macro-economic stability are pivotal in influencing farmers' willingness and ability to invest in soil conservation (Pandey, 2019). Research consistently demonstrates that the primary barriers to adoption are not technical but institutional, with incentive payments and regulatory approaches proving effective only when they outweigh the perceived risks and costs to farmers (Prager & Posthumus, 2010). Enforcement mechanisms and credible penalties are necessary for regulatory success. At the same time, personal motivation—shaped by awareness, education, and perceived long-term benefits—remains a crucial but often overlooked factor in driving adoption.

For policy frameworks to be truly effective, they must address both micro-level determinants—such as individual farmer motivations, resource constraints, and risk perceptions—and macro-level drivers, including institutional capacity, fiscal policy, and market infrastructure (Duff et al., 1992). Participatory, place-based approaches that integrate local knowledge and account for diverse socio-economic realities are essential for designing interventions that are both context-specific and equitable (Bharali et al., 2024; Prager & Posthumus, 2010). Ultimately, the integration of robust, adaptive policy frameworks with targeted economic and social interventions is vital for achieving sustainable soil management, enhancing food security, and building long-term climate resilience in rural India.

D. Case Studies and Zone-Specific Insights

Case studies and zone-specific insights across India reveal that effective soil conservation strategies must be regionally tailored to address the country's vast agro-ecological diversity and persistent adoption challenges. In the Indo-Gangetic Plains, conservation agriculture (CA) practices—including zero tillage, crop residue management, and diversified crop rotations—have led to significant improvements in soil health, organic carbon content, and crop productivity. Empirical studies report yield increases of 5–15% and reductions in input costs by up to 23% under CA, demonstrating both economic and environmental benefits (Sapkota et al., 2015; Pathak, 2022; Das et al., 2022; Rani & Paul, 2023). However, the widespread adoption of these practices remains constrained by insufficient policy support, limited farmer awareness, and restricted access to CA-specific machinery and market incentives. These limitations underscore the urgent need for targeted policy interventions, enhanced extension services, and investment in rural infrastructure to unlock CA's full potential. In the semi-arid tropics, the implementation of soil bunds, check dams, and integrated watershed management has been pivotal in reducing production risk and strengthening resilience to climate variability, particularly for resource-poor smallholders. Notably, watershed development initiatives in places like Kothapally have resulted in increased groundwater recharge, higher cropping intensity, and a dramatic reduction in sediment loads—by over 90%—directly boosting household incomes and food security (Garg et al., 2012; Anantha et al., 2021; Kumar et al., 2020). The success of these interventions highlights the value of participatory, community-driven approaches, which foster local ownership and sustain long-term benefits. In the Himalayan and central Indian regions, indigenous soil conservation practices such as terracing, organic amendments, and community-led conservation structures remain vital for maintaining soil stability and fertility. These traditional methods are highly adaptive to local topography and climatic conditions, but their effectiveness can be further enhanced through scientific validation, participatory research, and integration with contemporary soil management techniques (Yang et al., 2024; J. & T., 2023; Tanti & Jena, 2023; Mishra et al., 2021; Maurya et al., 2024; Shashikumar et al., 2022). Evidence from these regions indicates that blending indigenous knowledge with modern practices leads to higher adoption rates, improved productivity, and greater community empowerment.

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The arid zones, especially the Thar Desert, present unique challenges such as soil salinity, moisture stress, and widespread land degradation. Here, context-specific remediation techniques—including water harvesting, biochar application, and agroforestry—have proven essential for restoring soil health and supporting sustainable livelihoods. Increased vegetation cover and the use of bio-drainage species have significantly lowered water tables and reduced soil salinity, while agroforestry systems have improved soil structure and drought resilience (Rani & Paul, 2023; Kachhadiya & Pillai, 2025). These interventions underscore the necessity of science-backed, locally adapted solutions to address the diverse and complex soil conservation needs across India's agro-ecological zones. Ultimately, the integration of regionally appropriate practices, supported by robust policy frameworks and community engagement, is fundamental to achieving sustainable soil management and rural development in India.

Challenges in Implementing the Draft National Soil Policy

The implementation of the Draft National Soil Policy in India is fraught with a range of challenges that are deeply influenced by regional agro-ecological diversity and socio-economic realities. A primary concern is the widespread human-induced soil degradation resulting from land clearing, deforestation, and unsustainable agricultural practices, which collectively impact approximately 120.7 million hectares of land nationwide, with water erosion alone accounting for nearly 70% of this degradation (Das et al., 2022; Pathak, 2022). Rapid urbanisation has further intensified these pressures, leading to shrinking landholdings and limiting the potential for agricultural expansion, thereby exacerbating food security concerns (Rani & Paul, 2023). Coastal and arid regions face additional obstacles, such as high soil salinity, inadequate irrigation water, and shifting soil moisture and sunlight patterns, all of which complicate sustainable farming efforts (Kachhadiya & Pillai, 2025).

A significant technical challenge is the lack of standardised, region-appropriate agricultural machinery that minimises soil disturbance, alongside insufficient infrastructure for crop rotations and composting—both of which are essential for soil health restoration but remain difficult to implement due to resource constraints (Sapkota et al., 2015; Das et al., 2022). Furthermore, the absence of robust baseline data on soil carbon and biology impedes effective planning and monitoring of conservation strategies, while financial limitations, weak regulatory frameworks, and poor stakeholder coordination undermine the success of soil conservation initiatives (Bharali et al., 2024).

Local governance structures also face hurdles, including limited capacity for soil testing, inadequate access to mechanised conservation equipment, and ongoing land tenure conflicts, all of which hinder effective policy implementation (Pandey, 2019). The decentralised nature of agricultural governance in India places responsibility on state governments, but fragmented institutional arrangements and a lack of coordination often stall progress. Proposed solutions include establishing accredited soil testing laboratories, creating shared machinery pools, and forming democratically organised soil conservation districts to enhance community engagement and ownership (Prager & Posthumus, 2010). Ultimately, substantial government investment in research, extension, and coordinated policy frameworks is essential to overcome these multifaceted challenges and realise the goals of the Draft National Soil Policy.

IV. DISCUSSION

The research underscores that soil conservation in India is a multifaceted challenge that necessitates regionally tailored, integrated strategies. Conservation agriculture and watershed management have consistently delivered measurable improvements in crop yields, soil organic carbon, and water-use efficiency, while also enhancing resilience to climate variability—especially when these interventions are embedded within strong policy frameworks and supported by effective local governance (Chaudhuri et al., 2023; Sapkota et al., 2015; Garg et al., 2012; Anantha et al., 2021; Kumar et al., 2020). However, the full potential of these practices is often constrained by persistent socio-economic and institutional barriers. Limited access to extension services, lack of affordable credit, and insufficient farmer awareness about the long-term benefits of soil conservation inhibit widespread adoption, particularly among smallholders and marginalized communities (Chaudhuri et al., 2023; Singh, 2021; Tanti & Jena, 2023; Kumar et al., 2020; Jena et al., 2023; Tanti et al., 2024). The discussion also highlights the critical importance of integrating traditional and indigenous knowledge systems with modern scientific approaches. This integration is especially vital in the Himalayas and central India, where local practices such as terracing, organic amendments, and community-managed conservation structures have proven effective but require scientific validation and policy support for broader scaling (Yang et al., 2024; J. & T., 2023; Tanti & Jena, 2023; Mishra et al., 2021; Sahu et al., 2025). Despite notable progress, significant gaps remain—particularly in ecologically fragile and data-poor regions—where the adoption and scaling of conservation practices are still limited. The research calls for a "data revolution" to enable more precise, process-level research and to inform targeted interventions, which are essential for bridging knowledge gaps and optimising resource allocation (Chaudhuri et al., 2023). Moreover, the accelerating impacts of climate change and ongoing land use change continue to intensify soil degradation, making the development and implementation of adaptive, resilient soil management strategies more urgent than ever (Pathak, 2022; Rani & Paul, 2023; Gupta et al., 2024; Subbarayan et al., 2025).

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V. CLAIMS AND EVIDENCE TABLE

Claim	Evidence	Strength	Reasoning	Papers
Conservation agriculture improves yield, soil health, and reduces GHGs in Indo-Gangetic Plains	Supported by multi-year field trials, meta-analyses, and policy reviews	Strong	Consistent results from diverse, large-scale studies; policy reviews confirm scalability and impact	Sapkota et al., 2015; Pathak, 2022; Das et al., 2022; Rani & Paul, 2023
Watershed management and soil bunds increase productivity and reduce risk in semi-arid tropics	Robust empirical evidence from large-scale case studies and modeling	Strong	Multiple case studies and modeling exercises confirm productivity gains and risk reduction	Garg et al., 2012; Anantha et al., 2021; Kumar et al., 2020
Traditional soil management practices enhance soil fertility and resilience	Literature reviews and field studies show benefits, but integration with modern methods needed	Moderate to Strong	Benefits are well-documented, but need for scientific validation and integration with modern techniques	Yang et al., 2024; J. & T., 2023; Tanti & Jena, 2023; Mishra et al., 2021; Sahu et al., 2025
Socio-economic and institutional barriers limit adoption of conservation practices	Multiple studies identify lack of extension, credit, and awareness as key constraints	Strong	Repeatedly identified across regions and studies as primary obstacles to adoption	Chaudhuri et al., 2023; Singh, 2021; Tanti & Jena, 2023; Kumar et al., 2020; Jena et al., 2023; Tanti et al., 2024
Potassium depletion and imbalanced fertilization threaten long-term soil fertility	Long-term studies and reviews highlight negative K balances and need for integrated management	Strong	Empirical data and reviews consistently show declining K levels and call for integrated nutrient management	Das et al., 2022; Behera et al., 2020; Shashikumar et al., 2022
Policy incentives and extension services are insufficient for widespread adoption	Policy analyses and adoption studies show limited impact without local adaptation and support	Moderate to Strong	Evidence shows that generic policies are less effective; local adaptation and support are crucial	Chaudhuri et al., 2023; Singh, 2021; Tanti & Jena, 2023; Kumar et al., 2020; Jena et al., 2023; Tanti et al., 2024

VI. EVALUATION METRICS

A robust evaluation of the Draft National Soil Policy's effectiveness requires the adoption of both quantitative and qualitative metrics tailored to India's diverse agro-ecological zones. Key quantitative indicators include soil organic matter content, nutrient levels (notably nitrogen, phosphorus, and potassium), and microbial diversity, as these are fundamental to tracking improvements in soil health and long-term sustainability (Behera et al., 2020; Shashikumar et al., 2022). Establishing a network of accredited soil testing laboratories is essential for generating reliable, region-specific data that can guide adaptive policy and management decisions

(Bharali et al., 2024). In addition, a holistic evaluation framework should integrate the socio-ecological context by coordinating soil and water conservation efforts, recognising the interconnectedness of these resources in maintaining ecosystem resilience (Anantha et al., 2021; Garg et al., 2012).

Beyond biophysical metrics, qualitative indicators—such as the degree of community engagement, especially among marginalised and smallholder groups—are vital for assessing the inclusivity and social impact of soil conservation initiatives (Chaudhuri et al., 2023). These measures help ensure that the benefits of policy interventions are equitably distributed and that local knowledge and participation are valued. Furthermore, the widespread adoption of practical conservation practices—such as crop rotation, cover cropping, and conservation tillage—should be tracked as evidence of successful policy implementation at the grassroots level (Das et al., 2022; Sapkota et al., 2015). By integrating these diverse evaluation metrics, policymakers and practitioners can comprehensively assess progress, identify gaps, and refine strategies to achieve sustainable soil management outcomes across India.

VII. CONCLUSION

In conclusion, the synthesis of research highlights that integrated, region-specific soil conservation strategies are indispensable for sustainable agricultural development in India. Conservation agriculture and watershed management have consistently improved soil health, crop yields, and climate resilience, while the thoughtful integration of traditional and scientific knowledge has produced context-sensitive solutions, particularly in ecologically fragile regions (Sapkota et al., 2015; Garg et al., 2012; Yang et al., 2024). However, the widespread adoption of these practices remains hampered by persistent socio-economic barriers, such as limited access to credit, inadequate extension services, and insufficient farmer awareness, as well as institutional and technical challenges including fragmented governance and lack of standardized soil monitoring infrastructure (Chaudhuri et al., 2023; Singh, 2021; Bharali et al., 2024). Addressing these obstacles requires robust policy frameworks that incentivise sustainable practices, invest in capacity building, and prioritise the needs of smallholders and marginalised communities. Enhanced extension services, participatory approaches, and the establishment of accredited soil testing laboratories will be crucial for tailoring interventions to local conditions and ensuring inclusive benefits (Behera et al., 2020; Chaudhuri et al., 2023). Ultimately, the long-term sustainability of India's agricultural landscapes depends on a holistic approach that combines scientific innovation, traditional wisdom, and responsive policy support to build resilient, productive, and equitable agroecosystems for future generations.

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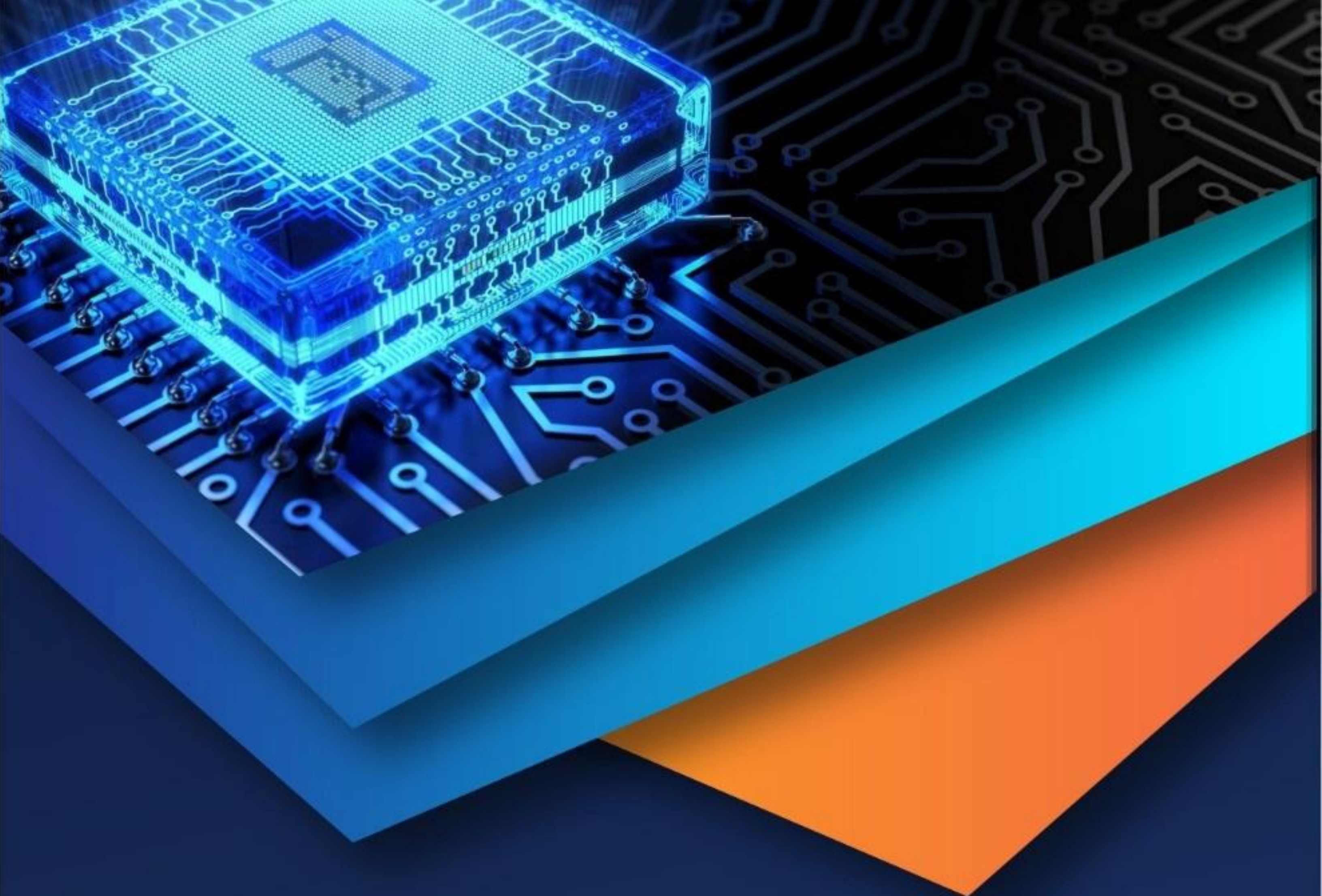

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