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Farmers' Adoption of Sustainable Agricultural Practices in Punjab: Barriers, Motivators, and Policy Implications

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Abstract

Punjab, the 'granary of India,' faces a severe agrarian crisis characterised by depleting groundwater, soil health degradation, paddy stubble burning, and declining farm incomes—largely attributed to decades of Green Revolution-driven monoculture. Sustainable agricultural practices (SAPs), including direct seeded rice (DSR), zero-tillage wheat cultivation, Integrated Pest Management (IPM), and crop diversification, have been promoted extensively by the Punjab Agricultural University (PAU) and the state government, yet adoption rates remain below desired levels. This paper examines the factors influencing farmers' adoption of SAPs in three agro-ecological zones of Punjab—Kandi (foothills), Central Plains, and South-Western Zone—drawing on primary survey data from 280 farm households across eight villages. Using a logistic regression model, the study identifies knowledge access, farm size, access to institutional credit, and peer influence as significant positive predictors of adoption, while debt burden, fragmented landholding, and input-supply constraints emerge as significant negative predictors. The paper further analyses the role of PAU's Krishi Vigyan Kendras (KVKs) and the state's Parali Management Scheme in shaping adoption decisions. Policy recommendations focus on restructuring subsidies, decentralising extension services, and integrating carbon credit mechanisms as incentives for sustainable farming.

Keywords: *Sustainable Agriculture, Punjab, Paddy Stubble Burning, Adoption Factors, Logistic Regression, Agrarian Crisis, Crop Diversification*

1. Introduction

Punjab's agricultural transformation since the 1960s has been both a success story and a cautionary tale. The state contributed approximately 32% of India's total rice procurement and 28% of wheat procurement during the 2022–23 rabi season (FCI Annual Report, 2023), firmly establishing its centrality to national food security. Yet this productivity has come at an ecological and social cost: the water table in Punjab is declining at a rate of approximately 0.5–1 metre per year in critical districts, soil organic carbon content has dropped well below the 0.5% threshold in 55% of agricultural land surveyed, and the annual burning of paddy stubble—involving an estimated 19.5 million metric tonnes in 2023—generates severe air quality crises that affect northern India every October–November (PPCB Report, 2023).

In response, both the central and state governments have promoted a suite of sustainable agricultural practices. The Parali Management Scheme of the Government of

Punjab (2018, revised 2022) offers incentives of Rs. 2,500 per acre for in-situ straw management. The National Mission on Sustainable Agriculture (NMSA), operationalised through the Punjab Agriculture Department, has promoted DSR adoption—a technology that saves an estimated 25–30% of irrigation water compared to transplanted paddy—as a central pillar of sustainable intensification. Despite significant public investment, adoption rates for DSR were only 16.4 lakh acres out of a potential 28 lakh acres during Kharif 2023 (Agriculture Department, Punjab, 2024).

Understanding why farmers adopt or resist sustainable practices is a question of considerable theoretical and practical import. This study builds on innovation diffusion theory (Rogers, 1983) and the Technology Acceptance Model (Davis, 1989) as adapted for agricultural contexts, while incorporating structural factors—particularly access to credit and land tenure—that shape decision-making in the Punjab farm household context.

2. Literature Review

The literature on agricultural technology adoption in India is extensive but concentrated on the Indo-Gangetic Plain and tends to focus on technology-specific adoption rather than holistic sustainable practice bundles. Feder, Just and Zilberman's (1985) foundational review identified farm size, human capital, credit access, and risk aversion as consistent predictors across contexts—a finding widely replicated in Indian studies, including Dhiman and Verma's (2019) Haryana-based study of zero-tillage adoption.

In Punjab specifically, PAU's Technology Assessment and Refinement programme has produced extensive farm-level data on DSR adoption. Singh et al. (2021) in the Punjab Journal of Agricultural Science found that DSR-adopting farmers were primarily from Central Plains districts, had larger land holdings (mean: 6.3 acres vs. 3.1 acres for non-adopters), and had received at least one KVK demonstration. Similarly, Brar and Sandhu (2020) found that social learning through farmer field schools significantly accelerated IPM adoption in Amritsar and Gurdaspur districts.

The stubble burning question has attracted particular research attention. The Indian Agricultural Research Institute (IARI) estimates that paddy straw burning releases approximately 1.28 kg of particulate matter (PM2.5) per tonne of straw burned, contributing significantly to the Delhi-NCR air quality crisis (IARI, 2022). Economic analyses by Tripathi et al. (2023) show that in-situ management costs exceed burning costs by approximately Rs. 1,800–2,400 per acre, explaining farmers' continued preference for burning despite regulatory prohibition.

The NITI Aayog's Reforms in Agricultural Marketing in India report (2020) and the Punjab Economic Survey (2024) together highlight that inadequate market linkages for diversified crops—particularly oilseeds and pulses—undermine the financial incentive to move away from the paddy-wheat monoculture, irrespective of sustainability awareness.

3. Methodology

This study employs a mixed-methods design with quantitative survey data as the primary evidence base, complemented by qualitative key informant interviews (KIIs). The study area comprises three agro-ecological zones: Kandi Zone (Ropar district), Central Plains (Ludhiana district), and South-Western Zone (Bathinda district), selected to capture variability in ecological conditions, land holding patterns, and exposure to extension services.

A stratified random sample of 280 farm households was drawn from eight villages (two to three per district), stratified by farm size (small: < 2 acres, medium: 2–5 acres, large: > 5 acres). Household-level interviews were conducted using a semi-structured schedule covering farm characteristics, cropping pattern, adoption history for six SAPs (DSR, zero-tillage, IPM,

soil health card use, in-situ straw management, and crop diversification), knowledge sources, credit access, and attitudes toward sustainable farming.

Adoption was operationalised as a binary variable (adopted = 1, not adopted = 0) for each practice. A composite adoption index (CAI) was also constructed, scored 0–6 based on number of SAPs adopted. Logistic regression was used to identify significant predictors of adoption, controlling for district. Twelve KIIs were conducted with KVK scientists, Agriculture Department block officers, and Progressive Farmers to provide contextual depth. Data analysis was conducted using SPSS v.27.

4. Results and Observations

The composite adoption index (CAI) showed that 38.2% of respondents had adopted 3 or more practices (high adopters), 41.1% had adopted 1–2 practices (moderate adopters), and 20.7% had adopted none (non-adopters). DSR adoption was the most common (54.3%), followed by zero-tillage wheat (49.6%), soil health card use (44.6%), and IPM (31.8%). In-situ straw management showed the lowest adoption rate (21.8%), consistent with the economic barrier identified in the literature.

Logistic regression results indicated that knowledge access (receiving at least one KVK training: OR = 3.12, $p < 0.01$), farm size (medium vs. small: OR = 2.47, $p < 0.05$), access to institutional credit from PACs or commercial banks (OR = 2.89, $p < 0.01$), and peer influence (having at least 2 neighbours who adopted: OR = 2.05, $p < 0.05$) were significant positive predictors of high adoption. Conversely, indebtedness to non-institutional lenders (OR = 0.43, $p < 0.05$) and highly fragmented holdings (OR = 0.61, $p < 0.05$) were significant negative predictors.

Zone-level analysis showed that Central Plains farmers had higher mean CAI (3.8) compared to Kandi (2.9) and South-Western Zone (2.3) farmers, reflecting better KVK access and infrastructure in Ludhiana district. South-Western Zone farmers demonstrated particularly low straw management adoption (11.4%), attributed to higher proportion of lease-farming (where long-term ecological investments yield limited private benefit) and lower KVK density.

KII narratives highlighted input supply gaps as a persistent barrier—particularly the non-availability of DSR seeding equipment at the village level during the critical sowing window. Several farmers noted that Parali Management Scheme payments had been delayed beyond the crop season in 2023, reducing their confidence in the scheme's reliability.

5. Discussion

The results confirm that SAP adoption in Punjab is not primarily a knowledge problem but a structural one. Farmers who have been exposed to KVK demonstrations are more than three times as likely to adopt, suggesting that the extension system works when it is accessible. The critical gaps are in the reach and regularity of that extension, particularly in peripheral zones with lower institutional density.

The role of peer networks in adoption—captured by the neighbourhood adoption variable—aligns with Rogers' (1983) diffusion of innovations framework, where early adopters catalyse broader uptake through social learning. Policy interventions that strategically support progressive farmers as demonstration hubs—as done through ICAR's lead farmer model—have shown promise in similar contexts and warrant scaling in Punjab.

The economic barrier to in-situ straw management remains the most intractable. The gap between the state incentive (Rs. 2,500/acre) and the actual cost differential (Rs. 1,800–2,400/acre) is narrow, and uncertain payment timelines further erode its effectiveness. The IARI and PAU have developed bio-decomposer sprays (PUSA decomposer) that can reduce costs, but technology delivery remains patchy.

The lease-farming problem, which affects an estimated 40% of cultivated area in Punjab (Punjab Agriculture Census, 2020), requires targeted policy attention. Lease farmers have limited incentive to make soil health investments—a classic principal-agent problem that the current incentive structure does not address.

6. Conclusion

Punjab's path to sustainable agriculture requires a convergence of technological, institutional, and economic interventions. This study demonstrates that adoption is multi-factorial and that universal prescriptions are inadequate—zone-specific strategies that account for ecological conditions, land tenure, credit access, and market linkages are essential.

Key recommendations include: (a) expanding KVK reach to sub-block level in Kandi and South-Western zones; (b) making Parali Management Scheme payments season-linked and front-loaded; (c) introducing a lease-farmer sustainability credit—a direct incentive for tenants to invest in soil health independent of landowner decisions; (d) promoting PUSA decomposer technology through mass demonstration camps before paddy harvest season; and (e) strengthening market linkages for diversified crops through dedicated procurement under the NAFED network.

Punjab's agrarian future depends on its ability to decouple productivity from ecological degradation. That transition demands not merely the availability of sustainable technologies but the dismantling of economic, institutional, and social structures that currently make unsustainable practices the rational default for the individual farmer.

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