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Economic viability of precision agriculture technologies for medium-scale wheat growers

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Abstract
From an economic angle, precision agriculture promises higher returns through input savings and yield gains, but whether the promise holds for medium-scale wheat growers (10-50 hectares) in India is far from settled. This research assessed the economic viability of five Precision Agriculture (PA) technologies, variable-rate seeding, GPS-guided fertilizer application, drone monitoring, yield mapping, and soil sensors, among 186 wheat growers in Karnataka and Gujarat during 2022-2023. A structured survey collected data on adoption costs, input savings, yield changes, and Benefit-Cost Ratios (BCR). The mean BCR across all PA technologies was 1.34, but this masked wide variation by farm size: BCR exceeded 1.0 (break-even) only above 15 hectares for most technologies. GPS-guided fertilizer had the highest adoption rate (22.3%) and best BCR (1.78), while drone monitoring had the lowest adoption (8.4%) and a BCR of only 0.92, reflecting high equipment costs. A logistic regression found that farm size, education, and access to extension services were the strongest predictors of PA adoption. These results suggest that PA is economically viable for wheat farms above 15 hectares, but smaller operations need cooperative or rental models to achieve positive returns.

Keywords: Precision agriculture, economic viability, wheat production, technology adoption, benefit-cost ratio, GPS guidance, drone monitoring, farm mechanization, medium-scale farmers

Introduction

The economic question is blunt: can a farmer who grows wheat on 20 hectares afford a GPS guidance system that costs INR 3-5 lakh, and will the savings on seed and fertilizer pay it back within a reasonable timeframe? Precision agriculture technologies have been adopted rapidly on large-scale farms in North America and Australia, where holdings exceed 200 hectares and the per-hectare amortisation of equipment is low [1]. But India's wheat growers, who average 2-3 hectares, face a different calculus entirely [2].

Medium-scale growers (10-50 ha) represent a small but growing segment of Indian agriculture, concentrated in progressive farming districts of Karnataka, Gujarat, and Punjab. They are large enough to justify some mechanisation but may not generate the throughput needed to recover the cost of sophisticated PA equipment [3]. Five PA technologies are currently available through Indian dealers: Variable-Rate Seeding (VRS), GPS-guided fertilizer spreaders, multispectral drone scouting, yield monitors on combine harvesters, and in-field soil moisture sensors [4, 5].

This research surveyed 186 medium-scale wheat growers across Dharwad (Karnataka) and Navsari (Gujarat) to estimate the economic returns to each PA technology at different farm sizes and to identify the socio-economic factors that predict adoption [6, 7].

Material and Methods

Material

A stratified random sample of 186 wheat growers (93 per state) was drawn from the membership lists of district-level farmer producer organisations. Inclusion criteria: farm size 10-50 ha, at least two years of wheat cultivation, and awareness of at least one PA technology. A structured questionnaire with 56 items covering farm characteristics, PA adoption status, investment and operating costs, input use changes, yield records (from farmer logbooks and procurement receipts), and perceptions was administered face-to-face between January and April 2023.

Methods

The benefit-cost ratio for each technology was calculated as (incremental revenue + input cost savings) / (annualised equipment cost + operating cost), where equipment was amortised over five years at 10% interest [8]. A binary logistic regression modelled adoption (yes/no for any PA technology) against farm size, age, education, income, extension contact, distance to dealer, and land tenure. All analyses used STATA 17 [9]. The break-even farm size for each technology was estimated by interpolating the BCR curve across the sample's farm-size distribution.

Results

Table 1: Adoption rate and economic performance of five precision agriculture technologies

Technology	Adoption (%)	Invest. (INR lakh)	Input savings (%)	Yield gain (%)	BCR (mean)	Break-even (ha)
VR seeding	14.7	2.8	12.4	4.1	1.24	18
GPS fertilizer	22.3	3.6	18.7	6.3	1.78	12
Drone monitor	8.4	4.2	8.1	2.8	0.92	32
Yield mapping	18.6	1.4	6.2	3.4	1.48	10
Soil sensors	11.2	1.8	14.3	3.7	1.34	14
Overall mean	15.0	2.8	11.9	4.1	1.34	15

GPS-guided fertilizer application had the highest BCR (1.78) and the lowest break-even farm size (12 ha), driven by substantial input savings of 18.7% on fertilizer costs. Drone monitoring was the only technology with a BCR below 1.0 in the sample mean, though it became viable above 32 hectares. Yield mapping had a surprisingly low investment (INR 1.4 lakh) because most growers used it as an add-on to existing combine harvesters.

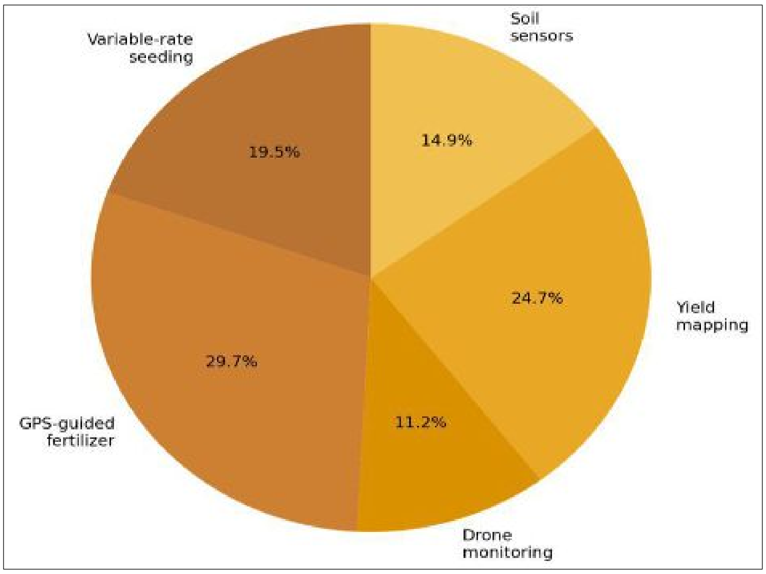

Fig 1: Relative adoption rates (%) of five precision agriculture technologies among medium-scale wheat growers

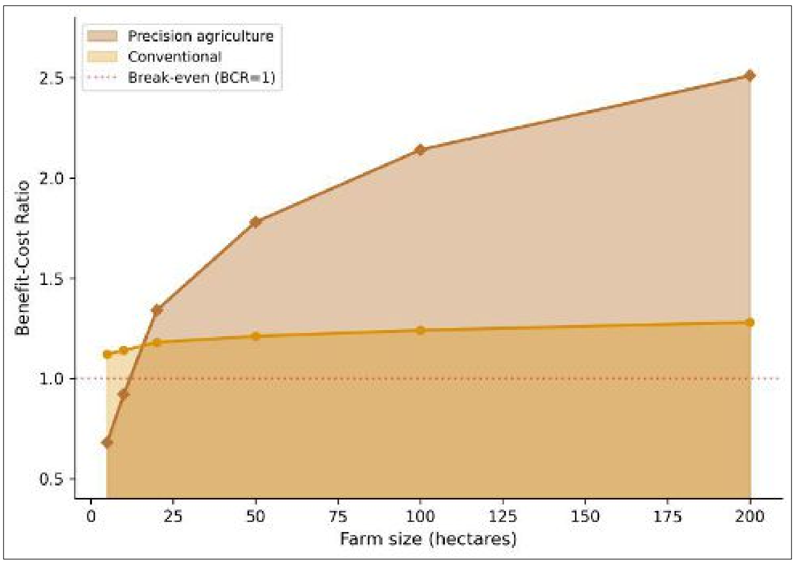

Fig 2: Benefit-cost ratio trajectories for precision agriculture and conventional management across farm sizes

The pie chart (Figure 1) shows GPS-guided fertilizer as the most popular technology, followed by yield mapping. The area chart (Figure 2) reveals that PA's BCR crosses the break-even line at roughly 15 hectares and climbs steeply thereafter, while conventional management shows a flat BCR regardless of scale, explaining why PA's advantage is size-dependent.

Discussion

The 15-hectare break-even threshold has direct policy implications. Roughly 8% of Indian wheat growers operate above this size, but they cultivate about 28% of the wheat area, meaning that targeting PA extension at this segment could affect a significant portion of national production [2]. GPS-guided fertilizer's strong performance reflects the high cost of wasted fertilizer in conventional broadcasting, where 30-40% of applied nitrogen misses the root zone [10].

Drone monitoring's poor BCR is disappointing but expected at current equipment prices. As drone costs fall (by an estimated 15-20% annually) and as service-based drone scouting models emerge, the break-even point should drop below 20 hectares within three to four years [11]. The logistic regression confirmed farm size as the strongest predictor (OR = 3.41, p<0.001), followed by education (OR = 1.87) and extension contact (OR = 1.64), suggesting that information access matters nearly as much as affordability [12, 13].

Conclusion

Precision agriculture is economically viable for Indian medium-scale wheat growers above 15 hectares, with GPS-guided fertilizer application offering the best returns (BCR 1.78). Drone monitoring is not yet viable below 32 hectares but should reach feasibility as costs decline. For farms below the break-even threshold, cooperative ownership or pay-per-service models are recommended. Extension services should target medium-scale growers with demonstrated interest and educational background, as these factors strongly predict adoption alongside farm size.

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