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# Phased integration of precision agriculture technologies on medium-sized farms in Texas: A techno-economic model for efficiency gains.

*Staged integration of precision agriculture technologies on mid-size Texas farms: a techno-economic framework for efficiency gains*

Staggered integration of precision agriculture technologies on medium-sized farms Texas: a techno-economic framework for efficiency gains

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## ABSTRACT

**Background.** Precision agriculture (PA) technologies — GPS guidance, section control, soil-moisture sensing, variable-rate application (VRA) and unmanned aerial scouting — are technically mature, yet their adoption remains uneven across US farm-size classes. Mid-size commercial operations of roughly 200 to 1,500 acres, which are common across South-Central Texas, frequently lack dedicated technical staff and face capital and learning constraints that slow uptake. **Objective.** This article develops and evaluates a staged integration framework designed to lower the capital and knowledge thresholds faced by these farms while producing measurable gains in input efficiency and yield stability within two to three seasons. **Methods.** The analysis combines a structured review of published adoption and profitability evidence (USDA Economic Research Service and peer-reviewed literature) with a techno-economic model of a representative 600-acre mixed-crop farm in the Bexar County region. Staged and all-at-once adoption strategies are compared on cumulative cash flow, simple payback, net present value (NPV) and sensitivity to key prices and agronomic responses. **Results.** Under base-case assumptions, staged integration keeps peak capital exposure below USD 6,000, reaches positive cumulative cash flow in Year 3, and yields a higher NPV than purchasing a complete package up front (about USD 30,700 versus USD 20,300), while carrying far lower downside risk. Expected input-cost reductions of 8–15 percent are consistent with published ranges. Payback is most sensitive to nitrogen prices and to the yield response obtained from variable-rate prescriptions. **Conclusions.** Sequencing diagnostic tools first, guidance and section control second, and imagery-based scouting third — supported by consulting that integrates agronomic diagnosis, financial modeling and operator training — makes precision agriculture accessible and profitable for mid-size Texas farms and contributes to broader national resource-use efficiency objectives.
**Keywords:** precision agriculture; soil-moisture sensors; GPS guidance; variable-rate technology; unmanned aerial systems; mid-size farms; techno-economic analysis; Texas; agribusiness consulting

## 1 INTRODUCTION

Precision agriculture refers to a family of information-intensive management practices that use location data, sensors and decision rules to match inputs to the spatial and temporal variability found within fields. Since the commercialization of yield monitors and differential GPS in the 1990s, the technology stack has expanded to include real-time kinematic (RTK) auto-steer, automatic section control on sprayers and planters, variable-rate seeding and fertilization, in-field soil-moisture telemetry and, more recently, multispectral imagery collected by small unmanned aerial systems

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(drones). Each component is commercially available, competitively priced and supported by dealer networks across Texas. Yet the national evidence shows that adoption is strongly stratified by farm size: large operations adopt earlier and more completely, while mid-size farms adopt selectively and often stop after the first component (Schimmelpfennig, 2016; McFadden, Njuki & Griffin, 2023).

The persistence of this gap matters for two reasons. First, mid-size operations manage a substantial share of cropland in Texas and in the United States as a whole. If they lag in adopting input-saving technology, the aggregate gains in fertilizer, fuel, water and pesticide efficiency that precision agriculture can deliver will be correspondingly smaller. Second, mid-size farms are precisely the operations for which cost efficiency is most consequential: they are large enough to depend on commercial margins and too small to absorb repeated years of thin returns. A technology that reduces input costs by even ten percent can represent the difference between reinvestment and contraction.

South-Central Texas illustrates the challenge well. Farms in and around Bexar County operate under a semi-arid to sub-humid climate, with high evaporative demand, erratic rainfall, and soils that range from deep clay loams to shallow, calcareous profiles within short distances. Crop mixes commonly combine grain sorghum, corn, cotton, wheat and forage, frequently integrated with cattle. irrigation, where available, depends on groundwater resources subject to regional management — the Edwards Aquifer Authority regulates withdrawals from the Edwards Aquifer — and on energy costs for pumping. This combination of within-field variability, water scarcity and diverse enterprises is exactly the context in which precision technologies should pay. It is also a context in which generic recommendations fail, because the value of any component depends on local soils, crop rotation and equipment already on the farm.

This article addresses a practical question: **how can a mid-size Texas farm sequence the adoption of precision agriculture components so that each step pays for itself, builds the data and skills needed for the next, and keeps financial risk within the tolerance of a family-owned commercial operations?** The contribution is threefold. First, the article synthesizes the adoption and profitability evidence relevant to mid-size farms. Second, it proposes a three-phase staged integration framework with explicit decision gates. Third, it evaluates the framework with a transparent techno-economic model of a representative 600-acre farm, including sensitivity analysis, so that consultants and producers can adapt the calculations to their own conditions.

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## 2 BACKGROUND AND LITERATURE

### 2.1 Adoption patterns by technology

The USDA Agricultural Resource Management Survey (ARMS) provides the most consistent national data on precision technology use. Successive ERS analyzes show that guidance and auto-steer systems have diffused faster, reaching a majority of planted acres for major field crops, because their benefits — reduced overlap, lower operator fatigue, longer working hours and fuel savings — are immediate, visible and largely independent of agronomic interpretation (Schimmelpfennig, 2016; McFadden et al., 2023). Yield monitoring and mapping followed, although many farms collect yield data without using it to change management. Variable-rate technology (VRT) has diffused more slowly and is frequently delivered through custom applicators and retail agronomy services rather than owned equipment (Erickson & Lowenberg-DeBoer, 2020). In-field soil-moisture sensors and drone-based scouting remain the least adopted components, concentrated in specialty crops, irrigated systems and large operations.

**Figure 1 – Approximate adoption rates of selected precision agriculture technologies by operation size class in the United States. Author compilation and rounding from USDA ERS analyzes and industry surveys, 2016–2023; values are indicative and intended for comparison across technologies rather than as precise estimates**

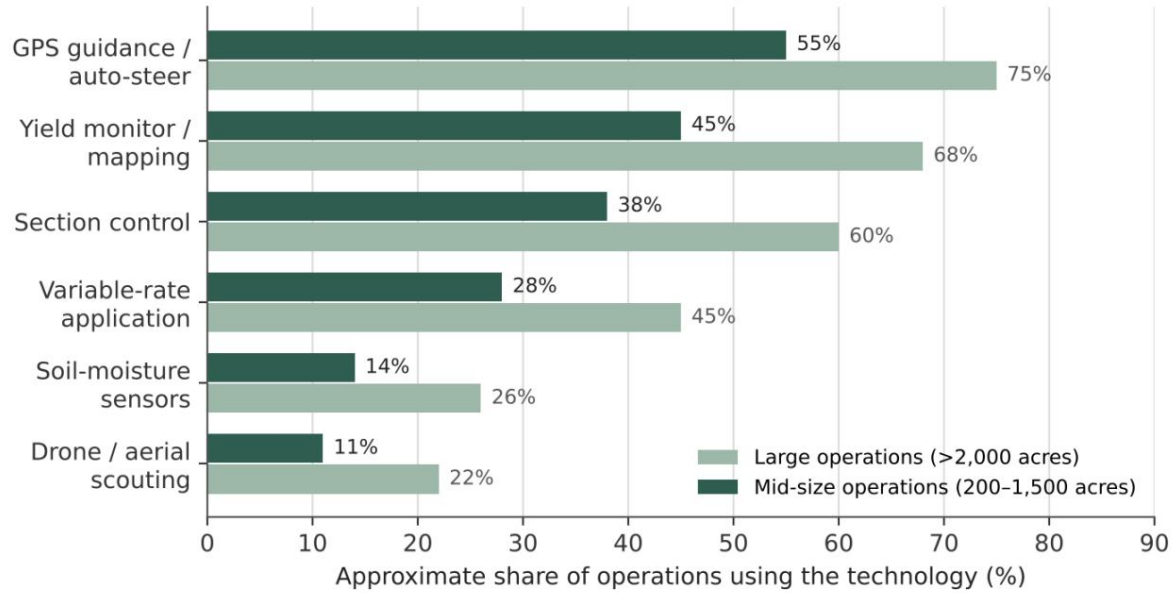


Figure 1 summarizes the general pattern. Two features are important for the framework developed here. First, the ranking of technologies is similar for mid-size and large farms; what differs is the level

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of adoption. This implies that the barriers facing mid-size farms are not primarily about technology suitability but about the conditions under which adoption occurs. Second, the gap between size classes is proportionally largest for the technologies that require data interpretation — VRT, sensors and drones — and smaller for guidance, which works "out of the box."

### 2.2 Profitability evidence

Studies of the farm-level economics of precision agriculture report positive but heterogeneous returns. Griffin, Shockley and Mark (2018) summarize the economic literature and conclude that guidance and section control show the most consistent net benefits, typically through reductions of 5–15 percentage in overlap of seeds, fertilizer and crop protection products and through fuel and labor savings. Variable-rate fertilization returns are more variable: they are stronger where within-field variability in yield potential is large and stable over time and where the farmer has the soil and yield data required to build defensible management zones. Schimmelpfennig (2016) found that the adoption of precision technologies was associated with modest increases in operating profit, with larger effects on larger farms, a result attributable partly to the ability to spread fixed costs over more acres. Lowenberg-DeBoer and Erickson (2019) emphasize that the economic case for precision agriculture is often understated in studies that look at one technology in isolation. Many benefits are complementary: GPS guidance creates the positional accuracy needed for section control and VRA; soil sampling and yield maps create the information base for prescriptions; and imagery is most valuable when it can be interpreted against existing zone maps. This complementarity is central to the staging logic proposed in Section 4.

### 2.3 Why mid-size farms lag

The literature and field experience point to three overlapping categories of barriers. **Capital and scale barriers** arise because many precision components have a fixed cost that is spread over fewer acres on a mid-size farm. **Knowledge and time barriers** arise because the operator is often simultaneously the manager, the equipment operator and the marketer; there is little time to learn new software, calibrate sensors or interpret maps. **Evidence barriers** arise because producers reasonably discount vendor claims and look for demonstrated returns on farms similar to their own, under local soils and weather. Notably, none of these barriers is about the existence of suitable technology. They concern sequencing, interpretation and demonstration — functions that agricultural consultants and extension services are well placed to provide (Anderson & Feder, 2007).

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**Table 1 – Main adoption barriers for mid-size farms and the corresponding design response in the staged framework**

| Barrier category | How it manifests on mid-size Texas farms | Design response in the framework |
|---|---|---|
| Capital and scale | High fixed cost per acre; reluctance to finance equipment with uncertainty returns | Start with low-cost diagnostics; use custom services for VRA; retrofit rather than replace |
| Knowledge and time | No dedicated technical staff; software and calibration burden falls on the operator | Consultant-led setup, short operator training, one decision rule per tool |
| Evidence and trust | Skepticism toward vendor claims; need for local, farm-specific proof | Simple payback calculation per phase; on-farm strip comparisons; documented results |
| Data integration | Data from different devices not linked; yield maps collected but unused | Single field-boundary and zone layer established in Phase 1 and reused in later phases |

## 3 METHODS

### 3.1 Research design

The study uses a mixed approach common in applied agricultural economics: a structured synthesis of secondary evidence combined with a deterministic techno-economic model of a representative farm. The representative-farm method is widely used by Texas A&M AgriLife and land-grant institutions to evaluate policy and technology options, because it allows transparent assumptions that individual producers can replace with their own data. Model parameters were drawn from published sources where available and from the author's field experience managing and advising commercial operations in Brazil and Texas, and are deliberately conservative.

### 3.2 Representative farm

The representative farm is a 600-acre mixed-crop operation in the Bexar County region. It plants approximately 250 acres of grain sorghum, 150 acres of corn, 120 acres of winter wheat and 80 acres of cotton in a typical year, with 160 acres served by a center pivot supplied from groundwater. The operator owns a 150-horsepower tractor, a 12-row planter, a 60-foot self-propelled sprayer and a combine, all between eight and fifteen years old. Fertilizer is spread by a local retailer that offers

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variable-rate application as a custom service. The farm employs the owner-operator, one full-time employee and seasonal labor at harvest.

**Table 2 – Base-case parameters of the representative 600-acre farm**

| Parameter | Base value | Source / note |
|---|---|---|
| Total cropped area | 600 acres | Representative farm definition |
| Irrigated area (center pivot) | 160 acres | Typical for regions with groundwater access |
| Annual nitrogen expenditure | USD 42,000 | ÿ USD 70/acre average across crops |
| Annual seed, herbicide and insecticide expenditure | USD 78,000 | Approximately USD 130/acre average |
| Annual fuel for field operations | USD 14,500 | Diesel for tillage, planting, spraying, harvesting |
| Annual pumping energy (irrigated area) | USD 16,000 | Electric pumping, ÿ USD 100/ irrigated acre |
| Overlap on planter and sprayer without control | 7% | Mid-range of published estimates for irregular fields |
| Discount rate | 7% | Approximates farm cost of capital |
| Analysis Horizon | 6 years | Typical useful life of electronics before upgrade |

### 3.3 Technology components and costs

The model considers five components: (i) grid or zone soil sampling with laboratory analysis; (ii) four to six capacitance-type soil-moisture probes with telemetry for the irrigated area and representative dryland fields; (iii) a GPS guidance retrofit with auto-steer for the tractor and automatic section control for the sprayer and planter; (iv) variable-rate fertilization, either through owned controllers or through the retailer's custom service; and (v) an entry-level multispectral-capable drone with processing software. Costs reflect 2022–2024 market ranges for retrofits and entry-level equipment and exclude financing charges.

**Table 3 – Illustrative component costs, expected annual benefits and payback on the**

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**representative farm**

| Component | Approximate cost (USD) | Main source of benefit | Expected payback |
|---|---|---|---|
| Zone soil sampling (first cycle) | 1,800 – 2,400 | Correcting over- and under-application of P, K and lime | 1-2 years |
| Soil-moisture sensors (4–6) with telemetry | 1,200 – 2,000 | Fewer irrigation events, lower pumping energy | 1.5 – 2 years |
| GPS guidance retrofit with auto-steer | 4,500 – 7,500 | Reduced overlap, fuel and operator fatigue | 2-3 years |
| Automatic section control (sprayer + planter) | 6,000 – 9,000 | Reduced overlap of seeds and chemicals | 2-3 years |
| Variable-rate controller (owned) | 10,000 – 14,000 | Zone-specific nitrogen and seeding | 3-5 years |
| Entry-level drone + software subscription | 3,000 – 5,500 | Previous detection of pest, stand and water problems | 2.5 – 4 years |

### 3.4 Economic indicators

Three indicators were computed for each strategy. Simple payback *(PB)* is the first year in which cumulative net cash flow becomes non-negative. Net present value is calculated as:

*NPV = ÿ (Bt ÿ Ct) / (1 + r)t, t = 0 … T*

where Bt are the annual benefits (input, fuel, energy and labor savings plus the value of yield changes), Ct are capital outlays and recurring costs (subscriptions, sampling, maintenance and training), *r* is the discount rate and *T* is the six-year horizon. Peak capital exposure is defined as the most negative value of net cumulative cash flow during the horizon; it approximates the maximum amount the farm must finance or draw from reserves, and it is the indicator most closely aligned with the risk tolerance of Family operations.

Overlap savings were calculated as the product of the input expenditure affected, the baseline overlap rate and the share of overlap eliminated by guidance and section control (assumed 70 percent). Irrigation savings were calculated as the number of irrigation events avoided through sensor-based multiplied by the cost scheduling per event. Yield effects were included only for variable-rate nitrogen and for early problem detection with imagery, and they were set at conservative values (1.0–1.5 percent of gross revenue on affected fields).

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### 3.5 Strategies Compared

**Strategy A — Full package in Year 0.** The farm purchases all components at once: soil sampling, sensors, guidance with auto-steer, section control, an owned variable-rate controller and a drone, with a total initial outlay of approximately USD 48,000. **Strategy B — Staged integration.** The farm implements Phase 1 (soil sampling and moisture sensors, about USD 3,200) in Year 0; Phase 2 (guidance with auto-steer and section control, about USD 14,000) in Year 2, after Phase 1 benefits have been verified; and Phase 3 (drone and software, about USD 5,500) in Year 3. Variable-rate application is purchased as a custom service from the fertilizer retailer rather than through an owned controller.

### 3.6 Sensitivity analysis

One-at-a-time sensitivity analysis was conducted on six parameters: nitrogen price, the yield response to variable-rate prescriptions, fuel price, the overlap reduction achieved, equipment cost and the number of irrigation events avoided. Ranges were chosen to reflect observed price volatility in 2020–2024 and the dispersion of agronomic responses reported in the literature.

## 4 THE STAGED INTEGRATION FRAMEWORK

The framework translates the complementarities identified in Section 2 into a sequence of three phases, each closed by a decision gate. The design principle is that **every phase must generate both a financial return and an information asset that lowers the cost or risk of the next phase.**

### 4.1 Phase 1 — Diagnosis (Season 1)

Phase 1 establishes the farm's data foundation at low cost. Field boundaries are digitized and verified; the soil is sampled by management zone (defined initially from soil survey maps, aerial imagery and the operator's knowledge) rather than by the entire field; and four to six soil-moisture probes are installed in the irrigated pivot and in representative dryland fields. The consultant builds a simple zone layer that will be reused in all later phases and trains the operator to read sensor dashboards using one decision rule — for example, irrigate when the weighted soil-water depletion in the root zone exceeds a crop- and stage-specific threshold, with reference evapotranspiration from the TexasET network Used as a cross-check.

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Benefits in Phase 1 come from two sources. Zone sampling typically reveals that some zones have been receiving phosphorus, potassium or lime they do not need while others are deficient; correction this redistributes rather than increases expenditure. Sensor-based irrigation scheduling avoids calendar-based or "feel"-based irrigation events, which directly reduces pumping energy and water withdrawals.

**Decision Gate 1 — proceed to Phase 2 when:**

- The zone layer has been verified in the field and stored in a format usable by guidance and application equipment.
- At least one season of sensor data shows avoided irrigation events, documented against prior-year pumping records.
- The operator can interpret soil-test results by zone and has agreed on maintenance or build-up rates with the consultant.
- A simple payback calculation for Phase 2, using the farm's own input and fuel expenditure, shows payback within three years.

**4.2 Phase 2 — Guide and control (Seasons 2–3)**

Phase 2 introduces GPS guidance with auto-steer and automatic section control on the sprayer and planter. These components deliver the most reliable returns documented in the literature and require minimal interpretation once installed. Retrofitting existing equipment with aftermarket guidance displays and section controllers keep costs well below the price of new equipment. In this phase, variable-rate fertilization is delivered through the retailer's custom application service, using the zone layer and soil-test results from Phase 1. This hybrid arrangement provides the agronomic benefit of variable-rate nitrogen and phosphorus without the cost of an owned controller.

**Decision Gate 2 — proceed to Phase 3 when:**

- Overlap reduction has been verified by comparing input purchases per acre with the two previous ones seasons.
- Yield maps (from the combined monitor or the custom harvester) have been collected for at least one season and aligned with the zone layer.
- On-farm strip comparisons of variable-rate versus uniform nitrogen have been laid out and harvested.
- Cumulative cash flow from Phases 1 and 2 is positive or projected to become positive within one season.

**4.3 Phase 3 — Scout and refine (Season 3 onwards)**

Phase 3 adds drone-based scouting once baseline data systems exist. The value of imagery depends

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on interpretation: an NDVI map is useful only when anomalies can be checked against zone boundaries, soil tests, sensor data and yield history. By Phase 3 the farm has these layers. Imagery is then used for three tasks: early detection of stand problems after emergence, targeted scouting for pests and diseases, and identification of irrigation non-uniformity under the pivot. The consultant supports interpretation in the first season and gradually transfers the routine to the operator or employee.

**Table 4 – Summary of the three-phase framework**

| Phase | Components | Information asset created | Typical first-year return |
|---|---|---|---|
| 1. Diagnosis | Zone soil sampling; soil-moisture sensors; field boundaries | Zone layer; soil-test baseline; irrigation record | Lower pumping energy; corrected P, K and lime |
| 2. Guide and control | Auto-steer retrofit; section control; custom VRA | Accurate as-applied and yield maps; strip trial date | 5–10% lower seed, chemical and fuel use |
| 3. Scout and refine | Drone with multispectral-capable sensor; processing software | Seasonal imagery archive linked to zones | Earlier problem detection; better pivot uniformity |

## 5 RESULTS

### 5.1 Cumulative cash flow

Figure 2 compares the cumulative net cash flow of the two strategies. Strategy A (full package) begins with an outlay of approximately USD 48,000 and recovers its investment during Year 4, ending the six-year horizon with cumulative net cash flow of about USD 39,500. Strategy B (staged) never exposes the farm to more than about USD 5,200 of cumulative negative cash flow, becomes positive in Year 3, and ends the horizon with cumulative net cash flow of about USD 43,800.

**Figure 2 – Cumulative net cash flow (undiscounted) of staged integration versus purchase of a full precision agriculture package in Year 0 on the representative 600-acre farm. Base case**

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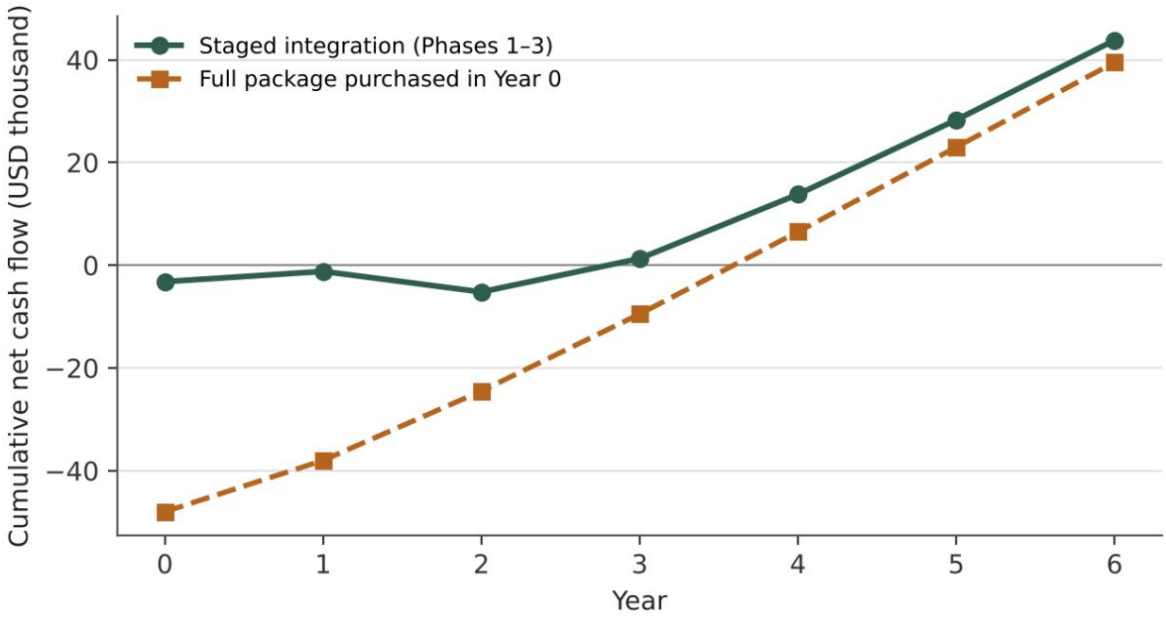
**assumptions as described in Tables 2 and 3**




The staged strategy performs slightly better at the end of the horizon for two reasons. First, it avoids the cost of an owned variable-rate controller whose benefits, on a 600-acre farm, can be captured at lower cost through custom application. Second, it postpones capital outlays until earlier phases have produced cash and data, which reduces the risk that equipment is purchased but under-used — a frequent outcome when packages are adopted before the operator has the skills or data to use them.

### 5.2 Economic indicators

**Table 5 – Economic indicators for the two strategies (base case, six-year horizon, 7% discount rate)**

| Indicator | Strategy A: Full package | Strategy B: Staged |
|---|---|---|
| Initial capital outlay (Year 0) | USD 48,000 | USD 3,200 |
| Peak capital exposure | USD 48,000 | USD 5,200 |
| Year in which cumulative cash flow turns positive | Year 4 | Year 3 |
| Cumulative net cash flow, Year 6 | USD 39,500 | USD 43,800 |
| Net present value at 7% | Approximately USD 20,300 | Approximately USD 30,700 |
| Annual input-cost reduction at full implementation | 11–15% | 9–13% |
| Equipment under-use risk | High | Low |

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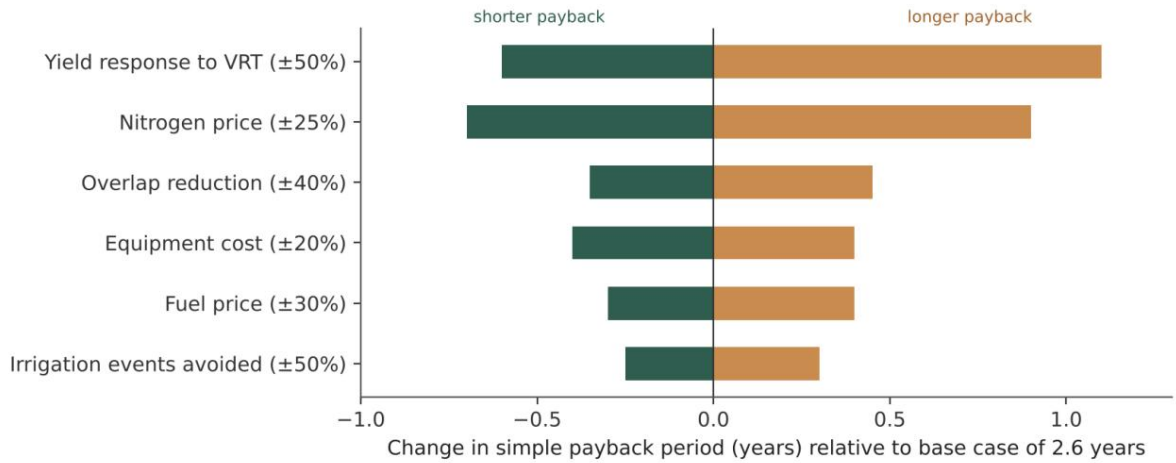
Input-cost reductions at full implementation are in the range of 8–15 percent of affected expenditure, consistent with the published ranges summarized in Section 2 and with results observed on comparable operations. The staged strategy captures slightly lower savings in the early years because Fewer components are in use, but this is offset by much lower capital exposure.

### 5.3 Sensitivity

Figure 3 presents the sensitivity of the staged strategy's simple payback to six parameters. Payback is most sensitive to the yield response achieved with variable-rate prescriptions and to nitrogen prices. Higher nitrogen prices shorten payback because each pound of nitrogen saved is worth more; a weak yield response lengthens payback by roughly one year. Equipment cost, fuel price, overlap reduction and avoided irrigation events have smaller effects. Under no single-parameter scenario examined does the payback of the staged strategy exceeds four years.

**Figure 3 – Sensitivity of the staged strategy's simple payback period to key parameters (one-at-a-time variation around a base case of 2.6 years). Ranges shown in parentheses**




### 5.4 Agronomic and operational outcomes

Beyond the financial indicators, the model and field experience indicate several operational outcomes. Yield stability improves when irrigation is scheduled by sensors rather than by calendar, because water stress at critical stages (flowering in sorghum and corn, squaring and boll set in cotton) is reduced. Guidance and auto-steer extend the effective working day, which matters during narrow planting windows following rain. Finally, the data layers built during Phase 1 and Phase 2 support

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Documentation requested by lenders, crop insurers and buyers, reducing administrative work — an often overlooked benefit of precision systems.

## 6 DISCUSSION

### 6.1 Interpretation

The results support the central proposition of this article: for mid-size farms, howprecision agriculture is adopted matters as much as *which* technologies are adopted. A full package can be profitable over a six-year horizon, but it concentrates risk in Year 0 and depends on the operator acquiring, in a single season, the data and skills needed to use each component. The staged approach reverses this logic. It starts with inexpensive diagnostics that produce immediate savings and a data foundation, adds the most reliable technologies next, and introduces interpretation-intensive tools only once the information needed to interpret them is in place.

This finding is consistent with the complementarity argument of Lowenberg-DeBoer and Erickson (2019) and with the observation that variable-rate technology is increasingly delivered through service providers (Erickson & Lowenberg-DeBoer, 2020). It also aligns with the extension literature's emphasis on "best fit" rather than "best practice" (Birner et al., 2009): the same technology can be profitable on one farm and unprofitable on its neighbor, depending on the sequence in which it is introduced and the data available to support it.

### 6.2 The role of consulting

The framework assumes that someone performs three functions that are often missing on mid-size farms: agronomic diagnosis (interpreting soil tests, sensor data and imagery), financial modeling (calculating payback with the farm's own costs) and operator training (setting up equipment and establishing simple decision rules). Equipment dealers provide setup and training but have an incentive to sell complete packages; extension specialists provide research-based guidance but have limited time for individual farms; and retail agronomists provide prescriptions but are linked to input sales. An independent consultant who combines these functions can sequence adoption in the farm's interest and document the results.

Walter's Agribusiness Consulting, LLC applies this model in Bexar County and surrounding counties. The approach draws on experience managing commercial operations in the Brazilian Cerrado, where large areas are managed with lean staffing and disciplined field protocols, and adapts these

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organizational methods to the soils, crops, water constraints and service networks of South-Central Texas.

**Practical checklist for consultants applying the framework**

- Collect two to three years of input, fuel and pumping records before recommending any equipment.
- Build the zone layer once and make sure every later device can read it.
- Use custom services (VRA, imagery, harvest mapping) before purchasing equipment of the same function.
- Require a written payback estimate, using the farm's own numbers, at every decision gate.
- Establish on-farm strip comparisons so results are demonstrated on the producer's own fields.
- Limit the operator to one new decision rule per season.
- Document results in a one-page seasonal summary that can also be used with lenders and buyers.

### 6.3 Broader implications

Mid-size farms manage a large share of cropland in Texas. Wider adoption of precision technologies among these farms contributes to national objectives for resource-use efficiency: lower nitrogen losses to water and air, less pesticide applied outside target areas, reduced fuel consumption and more efficient use of groundwater in regions where aquifers are under pressure. Because the staged framework reduces the capital threshold, it expands the number of farms for which adoption is financially rational, and therefore the aggregate environmental and productivity benefits. It also supports rural economic resilience by improving the profitability of family operations that anchor local economies

### 6.4 Limitations

The analysis has several limitations. The representative farm is a stylized construction; current farms differ in crop mix, equipment age, irrigation access and soil variability, all of which affect returns. The model is deterministic and uses one-at-a-time sensitivity analysis; it does not capture correlations between prices and yields or the full distribution of weather outcomes. Adoption-rate figures are compiled from several sources with different definitions and should be interpreted as indicative. Finally, the benefits of improved documentation and decision quality are difficult to quantify and are only partially included. Future work should validate the framework with multi-season data from a panel of mid-size farms in the region and extends the model to stochastic simulation.

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## 7 CONCLUSION

Precision agriculture is no longer limited by technology availability; for mid-size farms it is limited by capital exposure, operator time and the absence of locally demonstrated returns. A staged integration framework — diagnosis first, guide and control second, scout and refine third, with explicit decision gates — addresses all three. On a representative 600-acre farm in South-Central Texas, staging reduces peak capital exposure by roughly 90 percent relative to a full-package purchase, reaches positive cumulative cash flow one year earlier, and delivers a higher net present value (about USD 30,700 versus USD 20,300). Input-cost reductions of 8–15 percent and improved yield stability are achievable when recommendations are adapted to local conditions and supported by consulting that integrates diagnosis, financial analysis and training. The approach generates private returns for producers while contributing to broader efficiency and conservation goals.

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## CONFLICT OF INTEREST STATEMENT

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## REFERENCES

Anderson, J.R., & Feder, G. (2007). Agricultural extension. In R. Evenson & P. Pingali (Eds.), *Handbook of agricultural economics* (Vol. 3, pp. 2343–2378). Elsevier.

Birner, R., Davis, K., Pender, J., Nkonya, E., Anandajayasekeram, P., Ekboir, J., et al. (2009). From best practice to best fit: A framework for designing and analyzing pluralistic agricultural advisory services worldwide. *Journal of Agricultural Education and Extension,* 15(4), 341–355.

Erickson, B., & Lowenberg-DeBoer, J. (2020). *2020 precision agriculture dealership survey.* Purdue University and CropLife.

Griffin, T. W., Shockley, J. M., & Mark, T. B. (2018). Economics of precision farming. In D.K. Shannon, DE Clay & NR Kitchen (Eds.), *Precision agriculture basics.* ASA, CSSA and SSSA.

Lowenberg-DeBoer, J., & Erickson, B. (2019). Setting the record straight on precision agriculture

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adoption. *Agronomy Journal,* 111(4), 1552–1569.

McFadden, J., Njuki, E., & Griffin, T. (2023). *Precision agriculture in the digital era: Recent adoption on US farms* (EIB-248). USDA Economic Research Service.

Schimmelpfennig, D. (2016). *Farm profits and adoption of precision agriculture* (ERR-217). USDA Economic Research Service.

Texas A&M AgriLife Extension. (2023). *TexasET Network and irrigation scheduling resources.* Texas A&M University System.

USDA Economic Research Service. (2023). *Precision agriculture technologies and farm profitability.* US Department of Agriculture.

USDA Natural Resources Conservation Service. (2022). *Environmental Quality Incentives Program: Precision agriculture and nutrient management practice standards.* US Department of Agriculture.

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