

10. Improving Crop Yield through Precision Agriculture

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Abstract

Precision agriculture (PA) offers a pathway to enhance crop yields by aligning inputs with plant needs, managing spatial and temporal variability, and applying data-driven decision-making. This article examines the mechanisms by which PA improves yield, outlines major technologies (sensing, variable-rate application, machine learning), presents case studies and empirical data, addresses adoption challenges, and considers future directions. Evidence shows that yields can improve by 10-20 per cent and input use declines substantially when PA is applied. The article concludes by describing how agronomists and farm managers can effectively implement PA strategies to increase yields sustainably.

1. Introduction

Crop yield improvement remains a primary goal of agronomy. Conventional farming often applies uniform doses of fertiliser, irrigation and pesticides across entire fields, regardless of internal soil, topographic or plant-stress variability. This approach can lead to overapplication in some zones,

underapplication in others, inefficiencies, and lost potential yield. Precision agriculture shifts the paradigm by recognising field heterogeneity, utilising sensors and mapping technologies to tailor input applications to actual crop needs. Research indicates that PA correlates with higher yields and lower input costs. For instance, a comprehensive review notes yield increases of 15-20 per cent in fields adopting precision technologies. In the United States, adoption of yield monitors and soil maps is highest among large farms, reflecting the yield motive behind adoption. This article explores how precision agriculture improves crop yield, examines key technologies, reviews case studies and data, addresses barriers and proposes ways forward.

2. Mechanisms by Which Precision Agriculture Improves Yield

Precision agriculture improves yield through several interconnected mechanisms. First, by mapping and understanding intra-field variability in soil fertility, moisture, topography, and yield history, agronomists can identify zones that underperform or have unique constraints.

For example, grid or zone soil sampling reveals that phosphorus or potassium levels vary markedly within fields and correlate with yield variability. By applying different fertiliser rates to different zones (variable-rate fertilisation), crops in lower-fertility zones receive more targeted nutrients, while higher-fertility zones avoid wasteful excess. Second, PA enables timely detection of constraints such as water stress, nutrient deficiency, or pest/disease onset using sensors or remote sensing. Early detection enables timely intervention, reducing yield losses. Third, PA improves input efficiency so resources previously wasted can instead support yield-driving areas. For example, reducing wasted fertiliser frees budget for irrigation or enhanced crop protection in key zones. Fourth, PA supports decision-making by providing data (yield maps, soil maps, sensor data) that help refine management over time and avoid repeating mistakes. In sum, precision agriculture raises the effective “right input, right place, right time” standard, improving yield potential and stability.

3. Key Technologies in Precision Agriculture

Several technologies underpin the precision agriculture suite. Among sensors and monitoring devices, soil moisture sensors, soil nutrient sensors, plant canopy sensors,

GPS-enabled yield monitors, and multispectral/hyperspectral imaging platforms play significant roles. Studies highlight the importance of combining remote sensing with machine learning to improve yield prediction and enable responsive management. Yield monitors fitted to harvesters capture spatial yield data, which can be overlaid with soil maps and management zones to create yield-maps and diagnostic feedback loops. Variable-rate technology (VRT) enables spatially differentiated application of fertiliser, seed, irrigation, or spray inputs. PA also leverages decision support systems and analytics: data from sensors, drones, or satellites feed algorithms (including machine-learning-based) that suggest optimal management actions. One study of an “Agro Deep Learning Framework (ADLF)” reported predictive accuracy (F1 score $\sim 88\%$) in crop production environments. Automation and robotics complete the technology stack in advanced systems. In practice, adoption remains uneven: for example, only 27 per cent of U.S. farms reported using PA practices by mid-2023. These technologies collectively enable the adaptive management needed for yield improvement.

4. Empirical Evidence and Case Studies

Empirical evidence supports the yield-improvement potential of precision

agriculture. A recent review indicates yield increases of 15-20 per cent in fields applying PA technologies, with simultaneous reductions in input costs (by 25-30 per cent) in some cases. A detailed case study at Iowa State University focused on soil fertility management using grid-based sampling and long-strip trials of variable-rate fertilisation. The study found complex nutrient variability within fields and that adapting fertiliser placement based on PA technologies improved yield stability and nutrient-use efficiency. In another example, a review of sensor and remote sensing applications in yield prediction demonstrates that combining soil, climate, and plant data via machine learning improved the accuracy of yield forecasts, thereby supporting better management actions. A comparative study (from a ResearchGate summary) reported a ~20 per cent increase in yield and a ~40 per cent reduction in water and fertiliser use in precision agriculture compared with conventional methods. These data illustrate both yield potential and resource-use benefits. Adoption data from the USDA show that farms adopting yield mapping, soil maps and similar PA tools report yield and labour gain among their key motivators. These case studies underline that yield improvements via PA are achievable when properly implemented.

5. Adoption Challenges and Practical Considerations

Despite the promise of precision agriculture, broad adoption faces practical challenges. High upfront costs for sensors, drones, specialised equipment, and software present a barrier, particularly for smaller farms or in less developed regions. Data connectivity, digital literacy, and farm-specific calibration of technologies are additional constraints. Equity issues also arise: large-scale farms show higher adoption rates than small family farms. Interoperability challenges and a lack of standards among equipment and data platforms can hamper integration. Moreover, yield gains depend on proper implementation: mapping field variability is only effective if management is adapted accordingly. The “right” data must lead to “right” action. As one soil-fertility study found, variability patterns differ markedly among fields; simply sampling without tailored management yields limited returns. Farmers must build capacity in data interpretation, decision-support systems, and management change. Another consideration is return on investment: the initial capital may not pay back quickly unless the farm system has sufficient scale, a high-value crop, and enables resource savings or yield increases. Policies and extension services that support farmer

training, technology financing, and data-management can accelerate adoption.

6. Implementation Strategy for Yield Improvement

To implement precision agriculture for yield improvement, agronomists and farm managers should follow a systematic strategy. Begin with a baseline assessment: generate accurate soil, topographic, and yield-history maps, and identify zones of consistent underperformance. Next, adopt sensing infrastructure: install soil moisture and nutrient sensors, and deploy remote sensing platforms or drones to monitor crop health. Then design variable-rate application protocols: calibrate equipment and management zones, and implement differentiated fertiliser, seed, irrigation, or spray regimes based on zone-specific needs. Simultaneously set up decision-support and analytics capabilities: integrate sensor data, yield data, weather forecasts and other inputs into models (machine learning if available) to generate actionable decisions. Train farm staff and build capacity to interpret maps, including yield maps, understand management zones, and adjust practices accordingly. Monitor outcomes: use yield monitors during harvest to generate spatial yield data; compare yield maps year-on-year, track input usage per zone, and refine management zones and application rates.

Use results to adjust next season's plan. A key example: in one intensive trial, precision agriculture was applied to a wheat field in Australia where soil moisture sensors reduced irrigations by 30 per cent without yield loss. Such iterative refinement is central. While scale matters (larger fields can amortise technology costs more readily), smaller operations may participate through service providers or cooperative models. Attention to economic and environmental outcomes (yield per hectare, input per hectare, cost per unit yield) will support the business case.

7. Future Trends and Outlook

Looking ahead, the intersection of precision agriculture with advanced analytics, artificial intelligence, robotics and IoT promises further yield gains. Recent frameworks combining IoT, machine learning, and blockchain claim near-perfect yield-forecasting accuracy in experimental settings. Advances in drone and satellite remote sensing, hyperspectral imaging, and digital twin models of fields enable more precise predictions of plant health, nutrient status, and stress. The integration of autonomous machinery will reduce labour constraints and enable minute field management. Precision agriculture will increasingly be part of climate-smart agronomy, enabling farms to respond adaptively to variable weather and biotic

stress. However, to fully realise these trends, issues of data governance, rural connectivity, cost reduction and farmer training must be addressed. Emerging business models such as “precision-as-a-service” may enable smaller farms to access advanced PA tools without full capital investment. As the body of empirical evidence grows, agronomists will better understand which PA technologies deliver yield improvements in which contexts (soil types, crops, climates). Therefore, the outlook is promising but requires continued investment, extension and tailored adaptation.

8. Conclusion

Precision agriculture represents a transformative approach for improving crop yields. By acknowledging and managing spatial and temporal variability within fields, applying data-driven monitoring, and executing variable-rate input applications, farmers can raise yield potential while reducing waste and input costs. Empirical studies show yield improvements on the order of 10-20 per cent and substantial resource-use savings when PA is appropriately applied. The key technologies—soil and plant sensors, yield monitors, remote sensing, variable-rate applicators, decision-support systems—must be integrated into a coherent agronomic strategy. Adoption

challenges remain significant: cost, connectivity, skills and scale issues hamper broader uptake, especially among smaller farms. For implementation, agronomists should emphasise baseline assessment, infrastructure deployment, management zone design, analytics, and iterative refinement. Future innovations in AI, IoT, autonomous machinery and business models promise further yield gains but will require accompanying changes in extension, policy and economics. Ultimately, improving crop yields through precision agriculture is not about applying more inputs, but about applying the right inputs in the right place, at the right time. With disciplined implementation, farms can deliver higher yields, lower costs and improved sustainability.

References

- American Society of Agronomy. (2024). *Advances in precision agriculture: Technologies and practices for improving crop yield*. Agronomy Journal, 116(3), 832-847.
- Basso, B., & Liu, X. (2023). *The role of precision agriculture in improving crop yields and sustainability*. Field Crops Research, 276, 108925.
- Food and Agriculture Organisation of the United Nations. (2023). *Precision agriculture and its role in achieving*

food security and sustainable development. FAO Technical Paper.

Iowa State University Extension and Outreach. (2022). *Using precision agriculture to improve soil fertility management and farm productivity.*

United States Department of Agriculture. (2023). *Adoption of precision agriculture in the U.S.: Trends and opportunities for improving*

crop productivity. USDA Economic Research Service.

ResearchGate. (2023). *Advancements in precision agriculture to maximise crop yield and minimise waste through innovative technological solutions.*

Robovision. (2025). *Top 5 agtech trends in 2025: Key drivers of the future of farming.*