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Precision Farming: Making Every Square Meter Count

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Abstract

Precision farming is a modern, technology-driven approach to agriculture that aims to optimize crop production through the efficient and site-specific management of farm resources. By integrating technologies such as GPS, GIS, drones, remote sensing, soil sensors, variable rate technology and artificial intelligence, it enables farmers to identify field variability and apply inputs according to specific crop and soil requirements. These practices help improve productivity, reduce input costs, minimize resource wastage and promote environmental sustainability. Although high initial investment, limited technical skills and inadequate digital connectivity remain significant barriers, precision farming offers considerable opportunities for smallholder agriculture in India. Innovative approaches such as custom hiring centres, Farmer Producer Organizations, affordable sensors and mobile-based advisory services can improve accessibility. The integration of emerging technologies with farmer-oriented extension services will be crucial for making precision farming more affordable, inclusive and sustainable.

Keywords: Precision farming; Smart agriculture; Artificial intelligence; Remote sensing; Variable rate technology; Sustainable agriculture

Introduction

In this era, agriculture is no longer defined only by mechanical power. Modern farms now use data-driven technologies like sensors, GPS, drones and various software to help farmers raise their income and crop production with a level of accuracy that traditional methods were never able to achieve. This shift matters because the number of people on Earth keeps climbing, while the area of farmland is not increasing at the same pace. Farmers must now grow more food using the same, or even fewer, resources such as water, land and fertilizer (Gebbers & Adamchuk, 2010).

Ask an old farmer in Hardoi or Lucknow about his field and he will tell you that no two corners behave alike. Near the canal the soil stays wet for days; near the road it cracks in the April heat. One strip turns yellow every year while the rest stays green. Yet the usual practice is to sow, irrigate and spread urea across the whole plot in one uniform way. The result is a strange mix of waste and shortage inside the same field. Precision farming tries to end this mismatch by helping farmers understand exactly what their field needs, instead of guessing or treating the whole field the same way. As a result, it not only increases production but also reduces the wastage of resources and lowers the cost of farming.

What is Precision Farming?

Precision farming is a modern technique of agriculture in which data, technology and sensors are used to study a field closely, such as its soil moisture, fertility and texture. Based on this information, water, fertilizer and other inputs are applied only where they are needed, instead of the same way everywhere. This helps improve soil health and crop yield over time.

This idea originated in the 1980s and 1990s together with the development of the Global Positioning System (GPS) and Geographic Information System (GIS), since these were the first to allow farmers to map field variability with great accuracy. Before these tools, a farmer could only remember roughly where the weak patches were. After them, every patch could be given an address, recorded on a map, and visited again season after season.

It helps to picture the field not as one large unit but as a chessboard of hundreds of small squares. Each square has its own story: how much water it holds, how much nitrogen is left from last season, whether weeds or insects are gathering there. Precision farming reads each

square, keeps a record, and responds to it separately. The work moves in a repeating loop of five stages, shown in Figure 1. The farmer observes the field, analyses what was seen, decides on a plan, acts on that plan, and then evaluates the result before the next season begins. Behind this loop sits a body of organised farm data, which researchers call agriculture informatics (Singh *et al.*, 2023).



Fig. 1. The five-stage working loop of precision farming

Key Technologies

A number of closely related technologies make up the foundation of today's precision farming. Their roles are summarised in Table 1.

Table 1. Core tools of precision farming and their use on the farm

Tool	What it does	Benefit to the farmer
GPS auto-steering	Steers machines on exact paths	Fewer repeated or missed strips
Drones and satellites	Capture crop images from the air	Spots stress before it is visible
Soil sensors	Record moisture, pH, nutrients live	Irrigate and feed on actual need
Variable rate machines	Adjust dose during a single pass	Lower input cost per acre
Farm apps and AI	Convert field data into advice	Early yield and disease alerts

Source: compiled by the authors from Gebbers and Adamchuk (2010), Singh et al. (2023) and Nautiyal et al. (2025).

GPS and GNSS guidance systems. Global navigation satellite systems enable tractors and other equipment to be steered automatically, reducing overlap and missed areas when planting, spraying or harvesting. It improves consistency over successive passes and reduces fuel consumption and input waste. For a driver, it also means less tiredness at the end of a long working day.

Remote sensing and drones. By using satellite imagery and unmanned aerial vehicles (UAVs) fitted with cameras, it is possible to identify changes in plant health, nitrogen deficiency and water stress long before these issues can be seen with the naked eye. A healthy leaf and a stressed leaf may look equally green to us, but they bounce sunlight back in slightly different ways, and special cameras can catch that difference. A ten-minute drone flight can therefore point the farmer to the exact corner that needs attention.

Soil and crop sensors. Sensors placed in the ground measure soil moisture, temperature, pH and nutrient content in real time. This information is then used by variable rate application systems to adjust the amount of fertilizer or irrigation as the machinery travels across the field. When these sensors are linked to the internet, the readings can arrive straight on the farmer's mobile phone, which is a core feature of next-generation smart agriculture (Nautiyal *et al.*, 2025).

Variable Rate Technology (VRT). VRT systems make use of field maps and sensor data to automatically vary the rate at which seed, fertilizer or pesticide is applied during a single pass, optimizing the inputs according to the specific needs of each local area rather than using an average field value. A review of field studies found that such practices can give the same or higher yields at a lower cost, and also cut greenhouse gas emissions (Balafoutis *et al.*, 2017).

Farm Management Information Systems (FMIS) and data analytics. Software programmes combine data from a variety of sources, like yield monitors, weather stations and satellite feeds, into central dashboards. Nowadays, machine learning models are employed to produce predictive insights, such as forecasting yield or identifying disease risk before an outbreak has a chance to spread. Some apps can even name a leaf disease from a single photograph. Artificial intelligence is now widely seen as a driving force that will shape how farming is done in the coming decades (Nautiyal *et al.*, 2024). Work on interpretable deep-learning models for classifying plant diseases illustrates how image-based diagnosis can be built into decision-support tools (Rathor *et al.*, 2026), while wider reviews discuss both the progress and the open problems of AI applications (Kotyal *et al.*, 2024).

What the Experience So Far Tells Us

The longest records of how farmers take up these tools come from the United States, where government surveys have followed adoption for over two decades. Auto-steering spread fast once growers saw the savings in fuel and time. Yield monitors, which log the grain harvested from each spot, also became common. Variable

rate equipment moved more slowly, as it demands more data, more skill and more money (Schimmelpfennig, 2016).

The same surveys show that big farms adopt first. On the largest holdings, most growers use GPS maps and guidance, and a fair share use variable rate tools, while smaller farms lag behind. For an average farm, the extra profit was positive but small, around one to three percent depending on the tool (Schimmelpfennig, 2016). That figure may not sound exciting, yet repeated every season across large areas, it becomes meaningful. It also explains why the spread has been slow and steady rather than sudden.

There is a second kind of gain that does not show up in the farmer's account book. When fertilizer, pesticide, water and diesel are used only where needed, less of them ends up in rivers, groundwater and the air. Lower input use also means lower emissions from making and applying these inputs (Balafoutis *et al.*, 2017). For a country facing falling water tables and rising fertilizer import bills, these savings matter at a national level.

Why It Hasn't Taken Over Everywhere

Nothing about this technology is cheap or easy to use. The equipment and software are very expensive, and many farmers are unable to afford them, especially since they are already working with thin profit margins.

There is also a significant skill gap. Simply owning the equipment does not mean a farmer can use it effectively. Understanding and acting on the data requires training that many farmers do not have. A drone map full of colours is of little value if nobody can explain what the red patches mean or what to do about them.

Another problem is connectivity. Many of these systems depend on good internet or mobile network access, which is often not available in remote agricultural areas. A sensor that cannot send its readings is little more than a stick in the ground.

Small Holdings, Real Possibilities: The Indian Case

In India the picture is different from that in the United States. A typical family owns a small piece of land, often under two hectares, and frequently split into scattered plots. A large self-driving tractor has no place on such farms. Even so, the core idea of precision farming, treating each patch according to its need, suits small farmers well, because every rupee saved on inputs counts for them. What has to change is the delivery model, not the idea.

Several routes look practical. Custom hiring centres and Farmer Producer Organizations can own drones, sensors and soil-testing kits and rent them out by the hour or by the acre, so that a farmer pays only for one spray or one test. Low-cost moisture sensors and free mobile apps are already entering rural markets, and prices continue to fall (Nautiyal *et al.*, 2025). Krishi Vigyan Kendras can run field demonstrations, where farmers watch a neighbour's plot perform better and learn by seeing rather than by reading. Targeted subsidies on drones and smart sprayers can bring down the entry cost. Finally, AI-based advisory services, available on a basic smartphone and in local languages, can act as a field expert in every pocket, helping close the skill gap without a scientist having to visit each village (Nautiyal *et al.*, 2024).

Precision farming may also make agriculture more attractive to rural youth. Flying drones, handling farm data, servicing sensors and offering advice to other farmers can become new village-level jobs. This could slow the movement of educated young people from villages to cities.

The Future of Precision Farming

Looking at today's trends, precision farming has a very good future, because AI is now also being used to improve machinery and to teach farmers in ways that reduce the skill gap. In the future, precision farming can also help by providing accurate data to anticipate pest outbreaks and weather-related risks, which would allow farmers to rely less on manual monitoring. Small farmers can also get access to this technology if affordable equipment is made available to them, or if subsidies are given on it, which would also benefit the population as a whole.

A few needs stand out for the years ahead. Sensors and drone services must become cheap enough for a farmer with one hectare. AI tools should explain the reason behind their advice so that farmers can trust them. Apps and machines from different companies should be able to share data with each other. Above all, every tool should be built around the farmer's real problems in the field, and be simple enough to use without a manual (Singh *et al.*, 2023).

Conclusion

Precision farming plays a very critical role in changing the way agricultural decisions are made, shifting from general practices to more data-driven and accurate ones. It is well known that the high price and lack of skills make it difficult to expand this technology to a larger population, but researchers and investors continue to trust precision agriculture, sharing the same goal of producing enough food while

protecting soil, water and air.

As things change, tools are slowly becoming more affordable and accessible, and the gap between large-scale industrial farms and smaller ones may start to decrease. For India, the real test will be whether a farmer with a small, scattered holding can use a drone service, a soil sensor or a phone-based advisory as easily as he uses a mobile phone today. If that happens, every square metre of Indian farmland can be made to count.

References

Balafoutis, A., Beck, B., Fountas, S., Vangeyte, J., Van der Wal, T., Soto, I., Gómez-Barbero, M., Barnes, A., & Eory, V. (2017). Precision agriculture technologies positively contributing to GHG emissions mitigation, farm productivity and economics. *Sustainability, 9*(8), 1339.

Gebbers, R., & Adamchuk, V. I. (2010). Precision agriculture and food security. Science, 327(5967), 828–831.

Kotyal, K., Nautiyal, P., Singh, M., Semwal, A., Rai, D., Papnai, G., Nautiyal, C. T., Malathi, G., & Krishnaveni, S. A. (2024). Advancements and challenges in artificial intelligence applications: A comprehensive review. *Journal of Scientific Research and Reports, 30*(10), 375–385.

Nautiyal, C. T., Nautiyal, P., Papnai, G., Mittal, H., Agrawal, K., Shivani, & Nandini, R. (2024). Importance of smart agriculture and use of artificial intelligence in shaping the future of agriculture. *Journal of Scientific Research and Reports, 30*(3), 129–138.

Nautiyal, P., Rai, D., Singh, Y. P., Papnai, G., & Raghav, D. (2025). Smart agriculture: Next-generation technologies for a sustainable future. Integrated Publications.

Rathor, A. S., Choudhury, S., Sharma, A., Shah, G., & Nautiyal, P. (2026). An interpretable generative feature fusion network with hybrid optimization for plant disease classification: GGMHO.Net. *Results in Engineering, 31*, Article 111445.

Schimmelpfennig, D. (2016). Farm profits and adoption of precision agriculture (Economic Research Report No. ERR-217). USDA Economic Research Service.

Singh, D., Nautiyal, P., & Raghav, C. S. (2023). Agriculture informatics for precision farming. *Food and Scientific Reports, 4*(3), 1–7.