

## Adoption of Precision Farming Techniques in Indian Agriculture

**Tenzin Norbu**

School of Environmental Studies, North-Eastern Hill University (NEHU), Shillong, India

### Abstract

In India, precision farming—sometimes called site-specific crop management—is quickly becoming a game-changer when it comes to increasing agricultural yields while decreasing resource consumption and protecting natural habitats. The triple whammy of increasing food production with decreasing resources is a problem for Indian agriculture brought about by increasing population pressures, decreasing landholdings, and climate variability. Farmers can maximize the efficiency of water, fertilizer, and pesticide use by customizing inputs to match the unique requirements of crops and soils through the use of precision farming tools. These techniques include GIS, GPS, remote sensing, soil sensors, and drone-based monitoring. There have been encouraging outcomes from using these methods in India, such as higher crop yields, lower input costs, better soil health, and less environmental degradation. The majority of India's farmers are smallholders, and they face unique challenges when it comes to adoption rates: high starting costs, a lack of technical understanding, and inadequate infrastructure. To increase the use of precision farming, the government is launching programs like the Digital Agriculture Mission (2021–2025), subsidizing micro-irrigation, and promoting services that are enabled by information and communication technology. To increase the accessibility, affordability, and scalability of precision agriculture across diverse agro-climatic zones, there must be closer cooperation between public officials, academic institutions, and private agri-tech firms. By encouraging resource-efficient, climate-resilient, and market-oriented farming systems, the broad adoption of precision farming techniques could ultimately transform Indian agriculture.

**Keywords:** Precision Agriculture, Site-Specific Crop Management, IS and GPS Applications, Remote Sensing, Soil Sensors

### Introduction

As part of a larger shift away from labor-and resource-intensive methods and toward knowledge-and technology-based ones, precision farming is quickly becoming an integral part

of India's agricultural landscape. The foundational idea of precision farming—also called smart farming or site-specific farming—is the application of the correct input—the right amount—at the right time—in the right location. A number of pressing issues, including decreasing landholdings, increasing input costs, climate variability, and the pressing need for sustainable resource usage, can be met by this method. Precision technologies like GIS, GPS, drones, soil and moisture sensors, and remote sensing tools have great promise for optimizing inputs like water, fertilizers, and pesticides in a nation where approximately 86% of farmers are small and marginal. Agriculture becomes more resource-efficient and eco-friendly with precision farming, which adapts management approaches to field variability, resulting in less wastage, higher crop yields, and more profitability.

The initial investment costs are considerable, farmers lack technical understanding, and there is limited infrastructure for data-driven agriculture; these factors have contributed to the uneven adoption in India, despite the benefits. However, farmers in areas such as Andhra Pradesh, Haryana, Punjab, and Maharashtra have reported increased resilience to climate stress, lower input costs, and higher yields as a result of pilot initiatives. While drone-based surveillance has improved pest management in paddy and cotton, horticulture crop output has been greatly enhanced by drip irrigation in conjunction with fertigation. The Digital Agriculture Mission (2021–2025), the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) to fund micro-irrigation, and the encouragement of private agri-tech startups to provide farmers with affordable solutions are all programs that the Indian government has launched in response to the potential of precision farming. Precision farming is more than just a new technology in India; it is a step in the right direction toward sustainable, market-oriented, and climate-resilient farming. Indian agriculture may achieve the double goals of increasing productivity and conserving resources through precision farming, which combines modern equipment with traditional wisdom, strengthens farmer training, and ensures supportive legislation. With dwindling supplies of water, land, and energy, the nation is struggling to meet the demands of an expanding population. Precision agriculture offers hope for a sustainable future by bringing more food production in line with supply.

### **Yield Improvement and Resource Efficiency**

Precision farming has made great strides in increasing agricultural yields and optimizing the use of resources. The use of insecticides, fertilizers, and water is often standard practice in

traditional farming, and it is applied uniformly throughout fields despite differences in soil type and crop needs. This leads to input wastage, inconsistent crop production, and rising expenses. Contrarily, precision farming makes use of technologies such as soil sensors, geographic information system mapping, unmanned aerial vehicles (UAVs), and remote sensing to regulate the timing, location, and amount of inputs.

Water, fertilizer, and pesticide usage can be maximized by farmers that implement precision irrigation and site-specific nutrient management (SSNM). As a result, production costs are reduced and environmental consequences are mitigated, and yields are increased by 15-25% while input requirements are decreased by 20-30%. An essential step towards the long-term sustainability of India's agricultural development, precision farming guarantees the same or greater yield with less inputs. Wheat, rice, cotton, sugarcane, and vegetable crops all react positively to precision farming technology, according to empirical research. This results in enhanced growth, increased yields, and better quality veggies.

#### Effects of Precision Agriculture on Indian Crop Yield and Resource Efficiency

Crop	Yield Improvement (%)	Fertilizer Saving (%)	Pesticide Saving (%)	Water Saving (%)	Source/Example
Wheat	18–22	20–25	15–20	30–35	ICAR studies, Haryana & Punjab trials
Rice (Paddy)	15–20	20–30	20–25	35–40	Precision water management in Punjab & Andhra Pradesh
Cotton	20–25	25–30	20–25	40–45	Maharashtra micro-irrigation projects
Sugarcane	18–24	20–25	15–20	35–50	Drip fertigation in Maharashtra & UP
Vegetables	20–30	25–30	25–30	40–50	Tamil Nadu precision horticulture projects

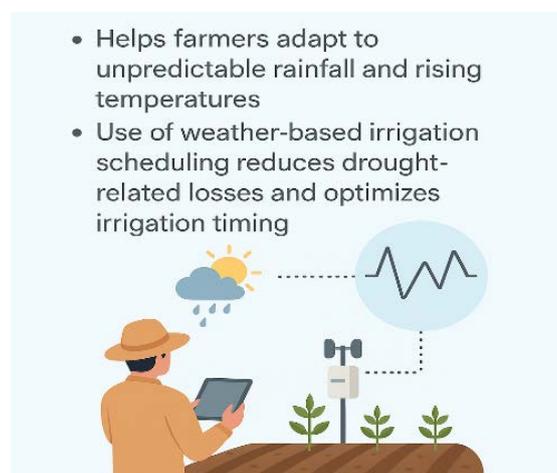
This information is derived from reports prepared by the State Agriculture Department, the FAO Water Productivity Database, and ICAR from 2019 to 2021.

### Crucial Findings

1. Across all main crops, precision farming reliably increases production while decreasing input costs.
2. The application of precision technologies is more advantageous for high-value crops and vegetables.
3. Drip and sprinkler irrigation greatly reduces water consumption, which is especially noticeable in crops like sugarcane and rice.
4. Less pesticide runoff and fertilizer leaching means less environmental damage.

### 2. Sustainability in the Face of Climate Change

As a result of the growing unpredictability caused by unpredictable rainfall, increasing temperatures, and severe weather events, climate resilience has emerged as a fundamental component of contemporary agriculture. One successful adaptation strategy to reduce crop losses during droughts and maximize water use efficiency is to adopt precision farming techniques, particularly irrigation scheduling based on weather conditions. Soil moisture monitoring, automated irrigation systems, and real-time weather forecasts allow farmers to tailor water application to crop requirements and current weather circumstances. This helps keep soil moisture balanced, lessens the chances of irrigation going over or under, and makes crops more resistant to heat and drought. Adopting such approaches is crucial for stabilizing yields, saving water resources, and guaranteeing food security in India, where the instability of the monsoon directly impacts agricultural output. Farmers may adapt to unexpected climates, reduce their vulnerability, and create resilience against future climate threats with the use of weather-based irrigation, as shown in the diagram.



Climate change poses a significant threat to the agricultural sector due to the direct impact that extreme weather events like droughts and heat waves have on crop yields. Irregular rainfall patterns frequently cause crop failures, soil moisture stress, and decreased yields in India, a country where the monsoon is still crucial to agriculture (over 50%). Climate resilience is an absolute need for long-term agricultural systems in light of increasing heatwaves and evapotranspiration rates.

Among the many options presented by precision farming, one of the most important adaptation tools is weather-based irrigation scheduling, which helps farmers overcome these problems. Soil moisture data, crop development stages, and real-time weather predictions allow farmers to precisely time the delivery of water. This method keeps crops resilient during important growth stages, lessens their susceptibility to droughts, and stops waterlogging from heavy rains. According to research conducted by the ICAR, precision irrigation has the potential to save 40-50% of irrigation water while reducing the chances of crop failure by about 30%. Farmers in drought-prone areas of Rajasthan and Maharashtra have shown that drip irrigation in conjunction with weather forecasting services can increase yield stability by as much as 25% compared to conventional flood irrigation methods.

Energy and financial savings are additional benefits of climate-resilient irrigation. Major expenditures in groundwater-dependent regions like Haryana and Punjab include energy and diesel, both of which are reduced by minimizing wasteful pumping. In addition, even when faced with climate stress, long-term productivity can be maintained with proper irrigation, which minimizes soil salinity and degradation. By lowering emissions from agriculture, maintaining supply chains, and protecting farmer incomes, these methods help ensure the safety of our nation's food supply.

#### Advantages of India's Climate-Resilient Irrigation Methods

Practice	Climate Risk Addressed	Benefit	Evidence/Examples
Weather-based irrigation scheduling	Erratic rainfall, drought	Stabilizes soil moisture, reduces crop failure risk	ICAR studies: ~30% reduction in yield loss (2020)

Practice	Climate Risk Addressed	Benefit	Evidence/Examples
Drip irrigation with fertigation	Drought, heat stress	Saves 40–50% water, improves nutrient-use efficiency	Maharashtra: +20–25% yield in sugarcane and cotton
Sprinkler irrigation	Heat waves, evapotranspiration stress	Maintains plant cooling, reduces evapotranspiration	Rajasthan wheat trials: improved resilience to heat
Rainwater harvesting + check dams	Rainfall variability, groundwater loss	Improves recharge, provides backup irrigation source	Haryana watershed projects: 15–20% higher yield stability
GIS & remote sensing tools	Unpredictable weather	Precision water management, reduced input wastage	Andhra Pradesh pilot projects on paddy and maize

*Sources: ICAR (2020), Central Ground Water Board (2019), FAO Climate Smart Agriculture Reports (2018).*

### Long-Term Soil Viability and Health

Proper management of minerals, organic matter, and biological activity is essential for sustaining healthy soil, which is the bedrock of sustainable agriculture. Soil degradation, nutrient mining, and over-application are all problems that can arise from the widespread use of fertilizers in conventional farming methods. One answer is precision farming, which uses cutting-edge technologies like soil sensors and VRT (Variable Rate Technology). Soil moisture, pH, and nutrient status may be tracked in real time by these technologies, which allow for the administration of inputs specific to each site. Farmers can keep soil from losing important nutrients and water from running off the land if they only water and apply fertilizer when it is really needed.

Maintaining soil structure, increasing microbial activity, and promoting long-term soil fertility are all outcomes of input use that is in sync with actual soil requirements. In heavily cultivated areas like Haryana and Punjab, this method lessens the chances of saltiness, soil acidification, and organic carbon loss. In addition, by utilizing precision approaches for sustainable soil

management, we may minimize environmental impacts like groundwater contamination and greenhouse gas emissions without sacrificing future crop output. By striking a balance between increasing productivity and preserving the environment, precision farming establishes a direct connection between soil health and sustainability.

### **Obstacles to Conversion**

Precision farming has the ability to revolutionize Indian agriculture, but there are a number of obstacles that have prevented it from being widely used. First and foremost, cutting-edge technology like drones, GPS, automated machines, and soil sensors demand a hefty sum to be invested. These expenses can be out of reach for many small and marginal farmers in a nation where they make up about 86% of the farming population, especially in the absence of large subsidies or cooperative arrangements. Furthermore, many farmers are unaware of the advantages of precision agriculture and lack the technical know-how to effectively utilize digital technologies, which hinders adoption. Inadequate availability of extension services and farmer training programs impedes effective implementation, even in cases where awareness is there.

The lack of adequate internet service in rural locations is another major obstacle. Access to real-time data, dependable internet connectivity, and advisory platforms based on information and communication technology (ICT) are still lacking in many regions of India. Digital networks play an essential role in precision farming, allowing for tasks like automatic irrigation scheduling, GIS mapping, and remote sensing. The potential of these technologies will remain untapped unless we invest in strong infrastructure. There is a disconnect between the promise of precision farming and its actual implementation due to these three obstacles: a lack of funding, inadequate information, and inadequate infrastructure. To tackle these issues and make precision agriculture more accessible and scalable across varied farming communities in India, we need coordinated policy support, new funding methods, and targeted capacity-building programs.

High initial investment in technologies (drones, sensors, GPS devices).



- **Limited awareness** among small and marginal farmers, who form **86%** of India's farming population.



- **Inadequate digital infrastructure** and connectivity in rural areas



### The Backing of Government and Policies

The Indian government and its policies have played a pivotal role in promoting sustainable agriculture and precision farming. In response to resource constraint, climate variability, and the prevalence of smallholder farmers, the Indian government has initiated multiple programs to promote digital agriculture and water-efficient technology. The goal of the Digital Agriculture Mission (2021–2025) is to enhance input-use efficiency and modernize farming processes through the integration of digital platforms, GIS mapping, and remote sensing instruments. Similarly, the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) promotes micro-irrigation, drip, and sprinkler systems to conserve water while increasing crop yields, with the slogan "Per Drop More Crop."

Also, in states like Maharashtra, Karnataka, and Haryana, horticulture and high-value crops have been supported by financial incentives including subsidies on drip irrigation, fertigation, and soil health monitoring. By lowering the barrier to entry for new technology, these policies level the playing field for small and marginal farmers interested in precision farming. To ensure sustainability in the long run, policy interventions are fostering climate-resilient agricultural systems and increasing efficiency in the use of available resources. But there are still problems, such as a lack of knowledge and a lack of acceptance, as well as a need for better internet infrastructure in rural regions. In this way, knowledge-intensive systems can replace input-intensive ones in Indian agriculture with the help of strong government and policy backing.

**Important Government Programs in India Promoting Precision Agriculture**

Policy/Program	Objective	Key Features	Impact/Outcomes
Digital Agriculture Mission (2021–2025)	Mainstream digital and precision technologies	Use of GIS, drones, sensors, AI platforms for farm management	Improved data-driven decision-making for farmers
PMKSY – Per Drop More Crop	Promote water-use efficiency in agriculture	Subsidy for drip/sprinkler irrigation, micro-irrigation expansion	Saved 40–50% water, improved yields by 20–30%
Soil Health Card Scheme	Ensure balanced fertilizer use and soil management	Soil testing and advisory on nutrient application	Reduced overuse of nitrogen, encouraged balanced fertilization
Mission for Integrated Development of Horticulture (MIDH)	Support horticulture with precision irrigation and fertigation	Subsidies for drip irrigation, fertigation units, protected cultivation	Increased area under micro-irrigation for horticultural crops
Subsidy Schemes for Farm Machinery	Encourage mechanization and precision equipment	Subsidies for GPS-enabled devices, drones, and automated machinery	Reduced cost barriers for small and marginal farmers

*Sources: Ministry of Agriculture & Farmers' Welfare (2021), ICAR Reports, FAO Agriculture Policy Database.*

**Conclusion**

Sustainable, resource-efficient, and climate-resilient agriculture is within reach in India through the implementation of precision farming techniques. Evidence from several states shows that precision technologies have greatly increased crop yields while decreasing input costs and environmental stress. These technologies include fertigation, drip and sprinkler

irrigation, drones, soil sensors, GIS mapping, and more. They have an important role in improving production with fewer resources, as empirical studies reveal yield enhancements of 15-25% and savings in water, fertilizer, and pesticide use of 20-40%. In addition to increasing yields, precision farming improves soil health, helps with climate adaptation, and increases food security by making agricultural systems more resistant to drought, unpredictable rainfall, and increasing temperatures. Meanwhile, low levels of technical knowledge, insufficient internet infrastructure in rural regions, and expensive starting investment costs continue to impede broad adoption. Problems with accessibility and affordability persist for the approximately 86% of India's farmers who operate on a small or marginal scale. Nevertheless, there is a lot of driving force behind the expansion of its use, especially in horticulture and high-value crops, thanks to initiatives like the Digital Agriculture Mission (2021–2025), PMKSY—Per Drop More Crop, and specific subsidies for micro-irrigation, fertigation, and soil health testing. Improving these policy frameworks, together with increasing digital infrastructure and training for farmers, is essential for closing the gap between theory and practice. Government organizations, academic institutions, agri-tech companies, and agricultural communities in India must work together if precision farming is to be successful in the future.

## References

- Central Ground Water Board (CGWB). (2019). *Dynamic groundwater resources of India*. Ministry of Jal Shakti, Government of India.
- FAO. (2018). *Climate-smart agriculture: Sourcebook (2nd ed.)*. Food and Agriculture Organization of the United Nations.
- ICAR. (2020). *Impact assessment of precision agriculture and micro-irrigation technologies in India*. Indian Council of Agricultural Research, New Delhi.
- Jat, R. A., Dagar, J. C., Sapkota, T. B., Yadvinder-Singh, R., & Stirling, C. (2020). Climate-smart agriculture in South Asia: Technologies, practices and policy innovations. *Journal of Integrative Agriculture*, 19(4), 843–858. [https://doi.org/10.1016/S2095-3119\(19\)62706-2](https://doi.org/10.1016/S2095-3119(19)62706-2)
- Kumar, R., Singh, R. K., & Sharma, V. K. (2019). Adoption of precision farming technologies in India: Status, challenges and opportunities. *Indian Journal of Agricultural Sciences*, 89(6), 965–972.

- Ministry of Agriculture & Farmers' Welfare. (2021). *Digital Agriculture Mission (2021–2025): Policy guidelines*. Government of India.
- Narayanamoorthy, A. (2017). Enhancing water productivity in Indian agriculture: Micro-irrigation way. *Indian Journal of Agricultural Economics*, 72(3), 321–336.
- National Bank for Agriculture and Rural Development (NABARD). (2020). *Precision farming for sustainable agriculture: Opportunities and challenges in India*. NABARD Occasional Paper.
- Singh, R. B., & Kumar, D. (2012). Climate change and water management in agriculture: Challenges and opportunities. *Current Science*, 102(12), 1643–1649.
- World Bank. (2020). *Transforming agriculture through digital technologies: The case of India*. Washington, D.C.: World Bank Group.