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The Food and Land Use Coalition

PRECISION FARMING IN INDIA

This summary document provides an overview of the state of precision farming in India. And also covers a literature review of impact studies conducted on precision farming in India. **It is a part of the larger CEEW study,** *Sustainable Agriculture in India 2021: What We Know and How to Scale Up.*

Sustainable Agriculture in India 2021: What We Know and How to Scale Up, is a handbook on the prevalence, practices and state of affairs of the 16 most promising sustainable agriculture practices in the country. It presents the economic, social and environmental impacts of these practices with recommendations on their potential to scale-up sustainable agriculture in India.

The study is available at: https://www.ceew.in/publications/sustainable-agriculture-india-2021

Image: Atul Loke for Panos Pictures/Food and Land Use Coalition

Precision farming (PF) is an approach to farm management that uses information technology to ensure that the crops and soil receive exactly what they need for optimum health and productivity.[1]Rather than applying similar inputs across the entire field, the approach aims to manage and distribute them on a site-specific basis to maximise long-term cost-benefit as well as prevent any waste.[2]

Like conservation agriculture, PF is a combination of different technologies rather than a one-off approach and allows for site-specific management (SSM) to efficiently utilize their resources and get economic gains.

Understanding and gaining more knowledge of the natural variability within a farm is one of PF's vital aspects.

Over the last few decades, many technologies have been developed for PF; they can be divided into 'soft' and 'hard.' Soft precision agriculture depends on visual observation of crops and soil management decisions based on experience and intuition, rather than statistical and scientific analysis. In contrast, hard precision agriculture uses all modern techniques such as GPS, remote sensing, and variable rate technology


Image: iStock

Some of the essential technology packages in precision farming:[3]

Satellite positioning systems (GPS): Enable farmers to monitor crop conditions using a network of orbiting satellites that send precise locational details to Earth from space.

Geographic Information Systems (GIS): Provide information on data parameters used to understand the relationships between factors affecting a crop on a specific site.

Sensors (optical): Provide essential information on soil properties, plant fertility and water status.

Grid soil sampling: A method for site specific soil management.

Remote sensing: Data collected through satellites that assist in evaluating crop health and related parameters.

Variable rate technology: Automates applying materials such as fertilisers, pesticides, seeds, and irrigation on the land.

Laser land levellers: Levelling of a field within a certain degree of the desired slope using a guided laser beam throughout the field.

Combine harvesters with yield monitors: Continuously measure and record the grain flow in the combine's clean grain elevator. When linked with a GPS receiver, a yield monitor furnishes the necessary data for yield maps.

Leaf coloured charts: An instant, easy and low-cost technique for N diagnosis of a crop (see Box 17 for more).

Automated irrigation systems: Systems that allow for minimal manual intervention apart from surveillance. Systems (drip, sprinkler, surface) is automated with timers, sensors or computers, or mechanical appliances.

Precision farming's linkages to FAO's agroecological elements

In principle, precision farming adheres to and promotes few agroecological elements as defined by the FAO

Elements	Description of agroecological linkages
Co-creation and sharing of knowledge	Knowledge sharing plays a central role in adopting and disseminating precision farming (PF) technologies suitable for a specific region. Most PF technologies are highly specialised, requiring a high level of expertise and technical knowledge to overcome any constraints.
Efficiency	The PF approach emphasises using precise amounts of inputs (fertiliser, water) to maximise yields, thereby managing cultivation more efficiently by reducing input use and associated costs.
Resilience	With the adoption of PF technologies (mobile apps, automation, and sensors deployed), farmers can get digital advisory services or weather-related forecasts, assisting them in timely decision making and helping them become climate-resilient.
Human and social values	Though technologies are an integral component of PF, willingness to adopt the technology depends upon the people, amongst other factors. When effectively adopted, certain technologies positively impact and become an integral part of the community.

A brief context in India

As a modern approach to farming, precision agriculture focuses on all aspects of resources (soil, water, nutrients) required for farming. However, in India, the practice is so far developed for nutrient-use efficiency (NUE) and water-use efficiency (WUE). PF in the Indian landscape is yet to become an integral part of mainstream farming systems. The literature and consultations from stakeholders also confirm that the practice is in a nascent stage in India.

However, technological advances and rising interest among scientific institutions bring new perspectives and reinvent the technology to suit all farm types and economic capabilities. For instance, the ICAR-National Rice Research Institute (NRRI) developed a low-cost Customized Leaf Colour Chart (CLCC) for nitrogen management in rice which achieved considerable commercial success, showcasing the scope for low-cost PF technologies in India (NRRI stakeholders). The Tamil Nadu, Precision Farming Project (TNPFF), initiated in 2004-2005, was crucial in spearheading drip irrigation. These automated systems are an integral component of PF and are gaining popularity, particularly for high-value crops.

In terms of government policies and schemes on PF, micro-irrigation has received much of the focus as seen through the various centrally sponsored schemes like *the National Mission on Micro Irrigation (NMMI)* 2010 that promotes drip/sprinkler systems. *Bringing Green Revolution to Eastern India (BGREI),* a programme under *RKVY* implemented in seven states provides financial support for Laser Land Leveller, a precise water management technique. PF technology is being developed and disseminated through the 22 Precision Farming Development Centres in the country, promoting "Precision Farming for hi-tech horticulture" through trials, experiments, and technology transfer.[4]

Precision farming: acreage, geographies, and cultivation details

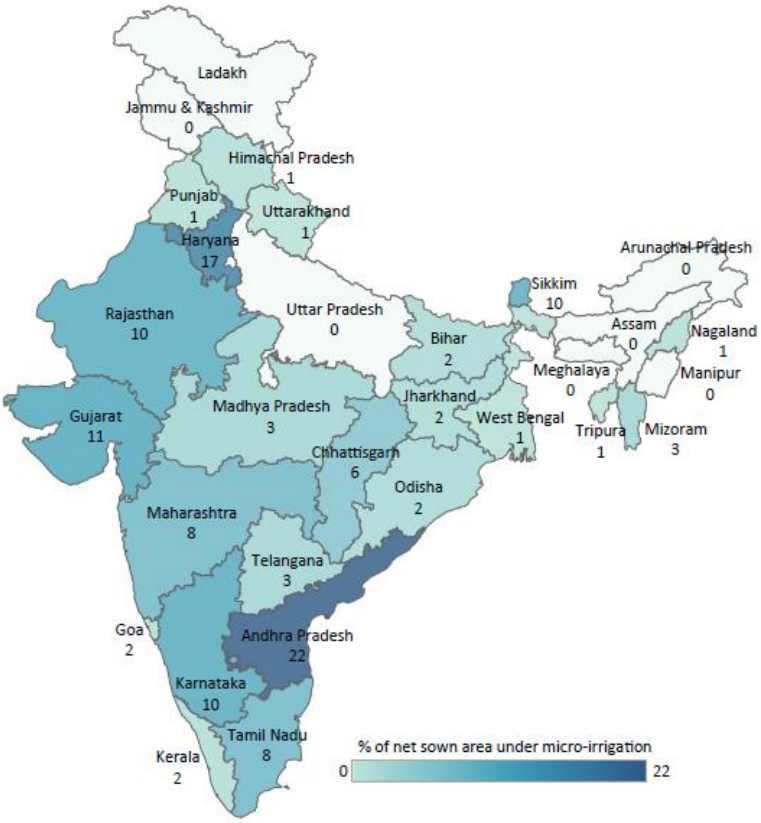
How much area in India is under precision farming? As the practice is at an early stage, there are no aggregate area estimates available for the country as a whole and for different techniques. However, precision irrigation techniques or micro-irrigation, such as drip and sprinkler irrigation, have a significant area coverage of around 9.2 million hectares in about 29 states (as of March 2017).[5] Out of this area, about 4.2 million hectares are covered by drip irrigation, while 4.9 million hectares are under sprinkler technologies.

At what farm size is PF practised? PF is practised by a limited number of farmers, often on a single field or on an experimental basis or commercial farms growing high-value crops. According to stakeholders consulted, in Karnataka, the complete package of PF technology is used only by large progressive landowners as its high cost limits its uptake.

How many farmers in India are practising precision farming? PF is practised by a limited number of farmers, often on a single field or on an experimental basis or commercial farms growing high-value crops. According to stakeholders consulted, in Karnataka, the complete package of PF technology is used only by large progressive landowners as its high cost limits its uptake. Since the area under micro-irrigation is around 9.2 million ha, then the range of farmers who are adopting PF is calculated by dividing the area with the landholding size of the implementers which are mostly semi-medium to medium. Through such methods we broadly estimate around 3 million of them to practise PF, especially micro-irrigation activities.

Where in India is precision farming prevalent? PF is practised by a minimal number of farmers in the country. Although there are no official aggregate figures available on a country basis, a rough estimate of around 3 million adopters is estimated. Most of them are located in the irrigated areas; about 1,000 farmers have adopted the LLL technique in western Uttar Pradesh and Haryana. For the CLCC, around 48000 copies are recorded to be sold as per the latest available data, which gives a generic sense of its adoption rate, which is low.[6]

Figure 1. Micro-irrigation is the most widespread PF technique in the country



Source: Department of Agriculture and Farmers Welfare 2017

Which are the major crops cultivated under precision farming in India? It is mostly commercial and horticultural crops in cooperative farms that find much scope as it is challenging for small farmers to utilise the farm machinery in fragmented plots. However, some aspects of PF, such as CLCC, can be adopted by farmers for many crops, including cereals. Simultaneously, drip cum-fertigation systems, variable rate applicators, and other sensors are more profitable for high-value crops given the high cost associated with them. Therefore, we mostly see farmers practising PF involved in the cultivation of fruit, vegetables, spices, flowers, medicinal and aromatic crops.

Impact of precision farming

This section considers the economic, social, and environmental impacts of precision farming.

ECONOMIC IMPACT

1. Yields

Through its various packages of mostly information and-technology-based solutions, precision agriculture helps farmers manage variability in fields by optimising resources and supporting them in making strategic decisions on crop management aspects. These aspects include site-specific crop management to help farmers accurately control field-specific variables like soil moisture and drainage, nutrient levels, crop yields, etc.

One of the larger initiatives is the 'Tamil Nadu Precision Farming Project (TNPFP),' where the yield advantages averaged from 30 per cent to 200 per cent for different crops (mostly horticulture) under PF than conventional by using irrigation cum-fertigation systems.[7] A study of orchard crops and vegetables showed the potential of PF techniques (micro-irrigation) to increase yields by 10 to 60 per cent compared to conventional methods.[8] A survey-based study showed a 42.4 per cent increase in the productivity of fruit crops from micro-irrigation and 52.7 per cent in vegetables.[9] In northern India, tractor-mounted N-sensors for wheat can increase wheat yields by about 3 per cent or 0.24 tonnes per hectare. The system increased the grain quality due to more effective protein content with increased homogeneity. The use of LLL increased the arable area by about 3-6 per cent due to a reduction in bunds and channels.[10]

To summarise, precision farming effectively improves yields on farms with a high degree of spatial soil variation. However, the yield advantages presented here concentrate on a few heterogenous PF technologies prevalent in the country. Comprehensive research on the impact of the Global Positioning System (GPS), automated analysis using remote sensors and Unmanned Aerial Vehicles (UAV), etc., on yields is mostly unknown. Long-term datasets on the impact on yield for the adopted PF techniques are also lacking.

2. Income

In general, input costs for some high-end technologies such as sprinkler irrigation, etc., will be higher due to the high initial installation cost. Still, over the years, it may return economic benefit. This is due to reduced water consumption while giving the farmers more flexibility to introduce new crops.[11] As emphasised earlier, low-cost PF techniques like CLCC (which cost only INR 110 or USD 1.50) show great scope for farmers to reap the benefits of managing their nutrient use efficiency and saving on fertilizers' input costs. However, the technique would require more labour and skills, which is a trade-off.

Although a few PF techniques reduce input costs and increase productivity significantly, their uptake is limited by our agriculture system's fragmented nature and farmers' low average annual incomes (INR 78,000 in 2015/USD 1000). Many of these farmers are averse to adopting new technologies that require an increase in investment to obtain higher yields. Stakeholders noted that rainfed farmers are hesitant to experiment as they perceive it as a risky endeavour that could affect yields.

Few studies give insights into the impact on income. However, the TNPFP study shows that PF increased cultivation costs by between 30 and 100 per cent, depending on the crop. But the increase in yields under PF was significantly higher (33 to 200 per cent) than in conventional systems, leading to higher net income for farmers overall.[12] Overall, the PF sector shows high potential to raise farmers' incomes, especially in the horticulture crops compared to cereals; however, more cost-benefit analyses are required for several PF technologies to understand how they can increase profits for farmers and long-term economic sustainability for farm collectives.

SOCIAL IMPACT

1. Human health

No relevant evidence was found linking PF to human health.

2. Gender

Studies that specifically link PF to gender are rare. However, household surveys in Haryana (Karnal, Kurukshetra, and Yamunanagar) and Punjab (Bhatinda, Amritsar, and Sangrur) found gender inequalities in PF. Women farmers never seemed to approach (often male) LLL service providers or hire male contractors. They usually ended up making deals through their children or a male relative. Therefore, social gender norms restrict women's participation in accessing new technologies.[13]

Drip irrigation and empowering women grape growers

Sahyadri Farms, a farmer producer company initiated in 2011 in Nashik, Maharashtra, is focused on creating value chains for small and marginal farmers who produce high-quality grapes for export. There is 100 per cent drip irrigation among the grape growers on this farm. One of the key performance indicators is its emphasis on gender diversity. At present, around 1,100 women (full-time and seasonal) are employed, and notably, 20 per cent of the women are farmer shareholders. About 50 per cent of women from tribal areas return to the farm during the peak grape season annually, and gender policies such as equal wages for equal work encourage women's participation in the farms.[14]

ENVIRONMENTAL IMPACTS

1. Soil and nutrients

The evidence suggests the most positive impacts of PF in reducing chemical application of fertilisers with methods of ground-based image analysis to detect the N requirement in real-time and location of weeds.[15] The GPS-systems and precise tractors' movement and combine operators reduce the structural damage to soil fauna and crops.[16]Although there is a lack of long-term evidence of PF's impact on soil quality, farmers in Tamil Nadu found that methods like drip irrigation and fertigation left the soil loose and promoted better root condition and yield.

While fertilisers, herbicides, pesticides, growth hormones, etc., are used in PF, their use is optimised to increase overall efficiency. One study finds that farmers can reduce nitrogen fertiliser by 10-20 kgs/hectare if applied to actual crop demand using the right PF technologies.[17]The use of N-sensors for wheat is able to save fertiliser applications by 10 per cent of the average N rate or 18 kgs N/hectare. It also reduces the N-leaching in cereals by 0-4 kgs N per hectare compared to an average N-leaching of 153 kgs N/hectare in conventional farming. Around 0-3 per cent is saved when variable rate applications are implemented. Patch spraying is likely to reduce herbicides by 50-75 per cent compared to conventional treatments as pesticides are applied explicitly to high-risk areas based on GIS-equipped ground sprayers.[18]

How customised leaf-coloured charts can increase N use efficiency?

Several trials conducted by the National Rice Research of India found that the Customised Leaf Coloured Chart is a useful diagnostic tool to monitor real-time nitrogen management in lowland rice. Farmers monitor the relative greenness of the rice leaf to assess the N status of the leaf and decide how much N to apply and in what quantity, thus ensuring N use efficiency.

Applying CLCC reduces the nitrate leaching by 29.8 per cent in direct-seeded aerobic rice compared to conventionally applied urea. When applied based on the recommendation of CLCC use, even neem-coated urea reduced the NO3 -N leaching by 39.8 per cent, which is considerable. The technique shows much potential to save on fertilizer use. Its N recommendation increases N recovery efficiently from applied urea by 9.1-12.2 per cent compared to conventional practices in transplanted rice. It shows the potential to save around 18.5-27.3 per cent in urea to produce the same level of yield.[19]

These early findings from the field show promise and indicate that PF could be a useful tool to manage long-term soil health and fertility better. However, long-term systematic studies across several agroclimatic regions in variable soil and topographic conditions are needed to establish reliable results for existing and emerging PF methods.

2. Water

Like soil, PF manages the spatial and temporal variability of water to attain higher water-use efficiency (WUE). Besides, the precise placement of chemical fertilisers limits these harmful chemicals and sediments into the surface and groundwater. PF techniques can also identify waterlogging risks, soil erosion, and salinity issues. Micro-irrigation techniques and precision LLL are the water-saving techniques widely-adopted in India.

Micro-irrigation techniques have made inroads in horticulture. They are found to significantly reduce traditional irrigation problems such as seepage, evaporation loss, higher energy cost, and low water productivity. Drip and sprinkler irrigation systems are highly efficient, promote better water infiltration in soil, prevent water run-off, and lead to water savings from 30 to 70 per cent and 35 to 60 per cent in orchard farms vegetables, respectively.[20]This targeted approach also maintains soil moisture at optimum levels. But farmers need to consider the soil and crop type to be cultivated, water source and quality, locational factors, and power availability before selecting these micro-irrigation methods. Water efficiency also tends to be higher where the cultivated area is levelled and smooth, with more water distribution efficiency, as observed after laser levelling the field.

Studies on PF's impact on the water are mostly focused on micro-irrigation techniques. There is lesser evidence for methods like LLL to understand its potential at all scales and areas other than the IGP, where it is most popular.

3. Energy

PF technologies also conserve energy through precise use. Decreases in fertiliser and herbicide application will reduce the energy consumption in producing and applying them on farms. Also, fuel is saved by attaining fewer overlaps due to operational efficiency, improved logistics, and better utilisation of farm

vehicles. The adoption of GPS guidance systems reduces overlaps when applying inputs and saves on labour and machine hours. In general, the practice can save up to 15-20 per cent of energy, according to stakeholders consulted from the Dryland Agriculture Project.

The literature on PF's impact on energy mostly relates to experiments on LLL in the Indo-Gangetic Plains and precision micro-irrigation methods. Observational studies conducted in Punjab and Haryana (6 districts) found LLL techniques saved about 755 kWh of electricity per hectare in the rice-wheat system due to reduced irrigation requirements.[21]

Micro-irrigation tends to reduce water consumption, thus substantially decreasing the electricity required for irrigation purposes. While this fact is reiterated in a few articles, little actual research has quantified these systems' energy savings. One study estimates that electricity savings could average 30.5 per cent as the smaller power units required in the system resulted in lower water use and fewer irrigation hours.[22] However, the studies mostly look at the energy saved from PF methods. Simultaneously, less research has quantified the actual benefits of energy and time savings, implying more experimental evaluations needed on this front.

4. Emissions

Researchers consulted from the Dryland Agriculture Project estimate around 25-30 per cent reduction of GHG from PF. This is backed up by research that compared traditional land levelling with laser land levelling. It found that LLL reduces GHG emissions because it decreases the time required to pump water, save energy, and avoid emissions, contributing to climate mitigation.[23]Cultivation time is also reduced by almost 2 hours/hectare in laser-levelled fields than traditionally levelled farms (Aryal et al. 2015). Further, PF also minimises nitrous oxide (N_2O, a potent GHG) and carbon dioxide (CO_2) by reducing the excessive use of synthetic fertilisers.

Other PF techniques like micro-irrigation can reduce GHG emissions as it reduces the pressure on groundwater sources. The CLCC also has good potential for reducing N_2O emissions by almost 13 to 21 per cent compared to conventional N application in puddled transplanted rice conditions (Nayak et al. 2017). But more long-term studies are necessary as the topic is still under-researched.

5. Biodiversity

No evidence found on linkages of PF to biodiversity.

Impact evidence

State of available research discussing the impact of precision farming on various outcomes.

Evidence Type	Yield	Income	Health	Gender	Soil and nutrients	Water	Energy	GHG emissions	Bio-diversity
Journals	11	1	0	0	17	11	16	1	0
Reports	0	2	0	4	1	1	1	0	0
Articles/ case-studies	0	0	0	0	0	0	0	0	0

Others **	1	2	0	1	3	0	5	1	0
Total	**12**	**5**	**0**	**5**	**21**	**12**	**22**	**2**	**0**

*** Thesis, guidelines, conference papers, etc*
Source: Authors' compilation

Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and the first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

Stakeholder mapping

The following institutions are involved in the research and promotion of precision farming; a few were consulted for this research:

Government institutions	Research/implementation institutions	NGOs/civil society organisations
National Committee on Plasticulture Applications in Horticulture (NCPAH)	M S Swaminathan Research Foundation	Precision Agriculture for Development
ICAR - Indian Agricultural Research Institute	Dryland Agriculture Project, UAS, Bangalore	Smallholder Adaptive Farming and Biodiversity Network (SAFBIN)
ICAR-National Rice Research Institute	ISRO, Ahmadabad	Utthan
National Bank for Agriculture and Rural Development (NABARD)	Indian Institute of Technology (IIT)	Kalpavriksh, Environment Action Group
Central Institute of Agriculture Engineering (CIAE)	Navsari University, Gujarat	Indo-Global Social Service Society
National Committee on Plasticulture Applications in Horticulture (NCPAH)	M S Swaminathan Research Foundation	Precision Agriculture for Development
ICAR - Indian Agricultural Research Institute	Dryland Agriculture Project, UAS, Bangalore	Smallholder Adaptive Farming and Biodiversity Network (SAFBIN)

Source: Author's compilation
Note: The stakeholders list is indicative and not exhaustive

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FOLU Coalition: Established in 2017, the Food and Land Use Coalition (FOLU) is a community of organisations and individuals committed to the urgent need to transform the way food is produced and consumed and use the land for people, nature, and climate. It supports science-based solutions and helps build a shared understanding of the challenges and opportunities to unlock collective, ambitious action. The Coalition builds on the work of the Food, Agriculture, Biodiversity, Land Use and Energy (FABLE) Consortium teams which operate in more than 20 countries. In India, the work of FOLU is being spearheaded by a core group of five organisations: Council on Energy, Environment and Water (CEEW), the Indian Institute of Management, Ahmedabad (IIMA), The Energy and Resources Institute (TERI), Revitalising Rainfed Agriculture Network (RRAN) and WRI India.

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