**Adoption of Precision Agriculture Technologies in Northern India: A Push-Pull Framework Approach**

**Abstract**

The human population continues to grow steadily with the shrinking resources being used for production situates great challenge against Indian farming system to attain food and environmental security. To counter these twin challenges in the country there is urgent need of application of modern Hi-tech technologies for enhancing the productivity and sustainability of the farming system for long term on scientific basis. Precision farming looks a win-win strategic advancement technology towards improving the potential of agricultural lands to produce crops on sustainable basis and to increase agricultural productivity in the future. However, their adoption, particularly among small and medium-scale farmers in developing nations like India, remains relatively limited. The agriculture and allied sectors are pivotal to the sustainable growth and development of the North Indian state’s economy. It contributes significantly to production, employment and demand generation through various linkages and meets the nutritional requirements of the population. But the sector is currently facing a dilemma as contribution of north Indian states to their state’s GSDP is decreasing which can be attributed to factors like inadequate use of modern technology, indiscriminate use of inputs coupled with improper management practices over a long period. Therefore, the need for focusing on the sustainable use of the inputs and increasing agricultural production has gained prominence in North India. Despite the several initiatives of government through different schemes and Precision Farming Development Centre’s, current status of the precision farming technologies in agriculture regarding its perception and factors influencing its adoption among farmers is not well known in North India. This study investigates the factors influencing the adoption of PFTs among farmers in Northern India through a push-pull framework approach. The present study was purposively conducted in North India. From North India, three states were selected randomly, namely Punjab, Haryana and Himachal Pradesh. Ludhiana, Hisar and Solan districts were purposively selected from each state based on highest number of farmers trained by the Precision Farming Development Centres located in these states. Further, two blocks were selected randomly from each district and from each block, 15 user farmers, who had received PFDC training and adopted at least one precision technology in agriculture or dairy, were selected using snowball sampling and thus, a total of 90 user farmers were surveyed using a structured open-ended interview schedule. Technologies considered included drip irrigation, laser land levelling, variable rate applicators, and automated dairy systems. Findings reveal that pull factors conditions that attract farmers to adopt PFTs play a dominant role. The most influential pull factors included higher yields (86.66%), saving of time and labour (78.89%), and government subsidies (75.55%). Other motivators included improved resource use efficiency, potential for year-round cropping, and environmental benefits. Conversely, push factors limitations of conventional agriculture compelling farmers to shift also significantly impacted adoption decisions. Key push factors included the non-availability of skilled labour (84.44%), low yield under traditional methods (76.66%), high input costs (67.78%), and concerns about product quality and environmental degradation. The study concludes that adoption is influenced by both the attractiveness of precision technologies and the challenges posed by conventional practices. However, adoption remains uneven, especially among smallholders, due to infrastructural, financial, and informational barriers. The findings suggest that policy interventions must address both motivational and structural constraints to facilitate broader adoption of PFTs in India.

**Key Words**: Precision Farming Technologies (PFTs), Push-Pull Factors, Adoption Behaviour, Northern India Agriculture, Sustainable Farming Practices

1. **Introduction**

Agriculture plays a vital role in India’s economy as it provides employment to 46.00 per cent of the population (Economic Survey 2024-25) and contributes 16.00 per cent to the GDP of country for the year 2024-25 (Economic Survey 2024-25). About 60.00 to 70.00 per cent of Indian population is dependent on agriculture and allied sectors for their livelihood (Arjun, 2013). But the agriculture and allied sector contribution which was more than 50.00 per cent during 1950 fell to 16.00 per cent during the period 2024-25. Environmental degradation due to overgrazing and perpetual land-use change in response to the increasing human population is another challenge (Chidawanyika *et al*., 2023).

However, the current state of agriculture faces substantial problems that needs to be tackled to ensure food security and sustainability. One of the primary issues is the need to feed a rapidly growing global population while at the same time reducing the environmental impact and preserving natural resources for future generations (Sanyaolu *et al*., 2024). To counter these challenges in the country there is urgent need of application of modern Hi-tech technologies for enhancing the productivity and sustainability of the farming system for long term on scientific basis. Precision farming (PF) looks a win-win strategic advancement technology towards improving the potential of agricultural land to produce crops on sustainable basis and to increase agriculture productivity in the future (Kumar *et al*., 2017).

Precision farming as an approach uses inputs in precise amounts to get increased average yields compared to conventional farming techniques. It is a comprehensive system designed to optimize production by using a key element of information, technology, and management (Kumar *et al*., 2017). It could be useful to increase production efficiency, improve product quality, improve the efficiency of crop chemical use, conserve energy and minimize potential environmental pollution. Robert *et al.* (1998) proposed three “R”s of precision farming viz. the Right time, the Right amount and the Right place. Later, the International Plant Nutrition Institute added another “R” to that list, “the Right Source” and more recently, Khosla (2008) proposed an additional “R”, the Right manner. The use of inputs (i.e. chemical fertilizers and pesticides) based on the right quantity, at the right time, and in the right place is commonly known as “Site-Specific Management”.

5 “R”s of precision farming

**Fig. 1 Five “R”s of precision farming**

Urbanization and globalization have significantly influenced the modernization of agriculture, driving mechanization and automation to meet the rising food demands of urban populations (Shahhosseini, 2013). This transformation has led to the adoption of quality standards, specialized equipment, and large-scale processing, especially in the dairy sector, improving efficiency and reducing consumer costs (Nicholson *et al*., 2011). Precision farming technologies (PFTs), such as sensors, robotics, and automated feeding systems, are increasingly being adopted globally for efficient resource use and enhanced productivity (De Koning, 2010). While countries like the U.S., Japan, and South Korea have advanced systems, developing nations such as India, Malaysia, and China have begun incorporating components of precision agriculture. The implementation of the PA involves the integration of smart technologies in both farming and livestock, allowing the farmer to manage field variability to maximize the cost–benefit ratio and also to continuously and automatically monitor the main animal performance indicators (Monteiro *et al.*, 2021). The evolution of precision agriculture is promising and its prospects are even more exciting. As technology continues to advance, we can anticipate further integration of artificial intelligence, machine learning, and automation in precision agriculture systems (Maurya *et al.,2024*).

 However, adoption remains limited, especially among smallholders. In India, small landholdings, infrastructure constraints, and limited awareness hinder the widespread use of precision technologies. Despite this, technologies like laser land levelling, precision fertilization, and dairy automation tools (e.g., milking machines, automatic analyzers) show promise in improving productivity and sustainability (Sahni *et al*., 2012). Given this context, understanding farmers’ perceptions and the push-pull factors influencing the adoption of precision farming technologies is crucial. Without farmer-level adoption, innovations risk underutilization. This study, therefore, explores farmers adoption of precision farming technologies with push and pull factors in Northern India, aiming to bridge the gap between innovation development and practical application.

1. **Methodology**

 The present study was conducted in Northern Zone of India. Northern Zone was selected purposefully which comprises of Jammu and Kashmir, Punjab, Haryana, Himachal Pradesh, Rajasthan and union territories of Delhi and Chandigarh because of maximum number of Precision Farming Development Centres (6) located in Northern zone. Out of Northern Zone, 3 States Haryana, Punjab and Himachal Pradesh were randomly selected. One district was purposively selected from each selected state based on highest number of farmers trained by the PFDCs located in these states. In this way from each district, 30 user, farmers were selected using snowball sampling constituting a total of 90 user farmers. The “user” sub-sample includes farmers who have attended training at PFDCs and were using at least one of the following precision farming elements: precision fertilization, precision irrigation, precision plant protection, precision tillage, Laser Land Leveler, precision weed management, precision sowing and sensors (soil, leaves, etc.) in agriculture and in case of dairy: automatic milk analyzer, milking machine, body weight, automatic temperature control, pedometer, automatic feeding, etc. Pull and push factors refers to the causes of adoption of PFT among people. Factors such as subsidy provided by government, saving of time, improved resource use efficiency etc. which attract people to adopt PFT are referred to as pull factors. People adopt PFT because of unsustainable conditions such as non-availability of labour, high cost of inputs, low yield associated with existing conventional technology etc. which are referred to as push factors. Open ended interview schedule was developed to know the pull and push factors for adoption of PFT. Frequency and percentage for each category was calculated and ranked accordingly.

**NORTH INDIA**

**PS**

**RS**

**PUNJAB**

**HIMACHAL PRADESH**

**HARYANA**

**PS**

**Hisar**

**Solan**

**Ludhiana**

**Ludhiana 1**

**Samrala**

**Hisar 1**

**Hisar 2**

**Solan**

**Kandaghat**

**RS**

**Ludhiana**

**Ludhiana**

**Ludhiana**

**SS**

**15 Users**

**15 Users**

**15 Users**

**15 Users**

**15 Users**

**15 Users**

**Users: 15\*6=90 respondents**

**PS: Purposive sampling**

**RS: Random Sampling** **SS: Snowball sampling**

**Fig.2 Sampling Plan**

**Results and Discussions**

* 1. **PRECISION FARMING TECHNOLOGIES ADOPTED BY THE USER FARMERS**

It is clear from the Table 1. that almost half of the user farmers had semi-automatic milking machine followed by drip irrigation system which was adopted by 41.11 per cent of the respondents. About 34.44 per cent of the user farmers had automatic analysers, 23.33 per cent of the farmers had seed drill, 21.11 per cent of the user farmers had Laser land leveller followed by Chisel plough (12.22 %) and Hi-tech community nurseries (7.78%).

**Table 1: Distribution of respondents according to the precision farming technologies adopted by the user farmers**

|  |  |
| --- | --- |
| **Category** | **Users (n=90)** |
| **Frequency** | **Percentage** |
| Drip irrigation system | 37 | 41.11 |
| Variable rate applicator  | 21 | 23.33 |
| Hi-tech community nurseries  | 7 | 7.78 |
| Chisel Plough  | 11 | 12.22 |
| Laser land leveller  | 19 | 21.11 |
| Semi-automatic milking machine  | 44 | 48.89 |
| Automatic analysers  | 31 | 34.44 |

**3.2 PULL AND PUSH FACTORS AFFECTING ADOPTION OF PRECISION FARMING TECHNOLOGIES (PFT)**

**3.2.1 PULL FACTORS AFFFECTING ADOPTION OF PRECISION FARMING TECHNOLOGIES (PFT)**

 Pull factors are those favorable conditions or benefits that attract farmers towards the adoption of precision farming technologies. An analysis of responses from user farmers revealed several key pull factors that significantly influenced their decision to adopt these technologies. As shown in Table 2, the most prominent pull factor identified was the *high yield obtained through precision farming technologies*, which was acknowledged by 86.66% of the user farmers. The enhanced productivity associated with precision tools and practices appears to be a major incentive, particularly in areas facing land and resource constraints. The second most influential pull factor was the *saving of time and labour*, reported by 78.89% of the respondents. This is likely due to the growing challenge of labour shortages and high wage rates, making mechanization and automation increasingly attractive. The use of precision technologies helps farmers manage these constraints more efficiently and contributes to increased profitability. Another crucial motivating factor was the *availability of government subsidies*, cited by 75.55% of the farmers, making it the third highest ranked pull factor. These financial incentives have significantly lowered the entry barriers for small and medium-scale farmers, promoting wider adoption of precision tools. The *improvement in resource use efficiency*, such as reduced use of water, fertilizers, and pesticides, was noted by 60.00% of the user farmers and ranked fourth. This indicates a growing awareness among farmers about optimizing inputs for cost-effectiveness and sustainability. The *possibility of year-round production of seasonal crops* was the fifth major pull factor, mentioned by 47.78% of respondents. This capability allows farmers to produce during off-season periods, enabling them to access premium markets and higher prices for their produce. Lastly, *environmental benefits* from adopting precision farming technologies were reported by 35.56% of the users. Although ranked sixth, this factor highlights the emerging consciousness among a section of farmers regarding the ecological advantages of precision practices. However, the lower percentage also suggests that economic motivations continue to outweigh environmental concerns for the majority of respondents. These findings underscore the importance of not only technological performance but also economic and institutional support systems in promoting precision agriculture. While productivity and profitability remain dominant motivators, targeted awareness and incentive programs could enhance the recognition of environmental benefits among farmers. The results of the study are consistent with the findings of Bewley J (2010)

**Table 2: Distribution of user farmers on the basis of their response to pull factors for adoption (n=90)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl. No.** | **Pull factors for adoption** | **Frequency (f)** | **Percentage (%)** | **Rank** |
| 1 | Subsidy provided by the government for precision farming technologies | 68 | 75.55 | 3 |
| 2. | High yield obtained with precision farming technologies | 78 | 86.66 | 1 |
| 3 | Improved resource use efficiency | 54 | 60.00 | 4 |
| 4 | Saving of time and labour | 71 | 78.89 | 2 |
| 5 | Environmental benefits due to adoption of precision farming technologies | 32 | 35.56 | 6 |
| 6 | Possibility of year-round production of seasonal crops | 43 | 47.78 | 5 |

**3.2.2. PUSH FACTORS AFFFECTING ADOPTION OF PFT**

Push factors are defined as the challenges or limitations associated with conventional farming methods that compel farmers to shift toward precision farming technologies. These factors often arise from inefficiencies, resource constraints, or declining returns in traditional practices. According to the data presented in Table 3, the most significant push factor identified by the user farmers was the *non-availability of skilled labour required for operating conventional technologies*, reported by 84.44% of respondents. This shortage has driven many farmers to adopt precision farming tools that reduce dependency on manual labour and increase operational efficiency. The second most important push factor, as perceived by 76.66% of the user farmers, was the *low yield associated with conventional farming methods*. This is largely attributed to the lack of precision in input application and the inability to mitigate adverse environmental conditions effectively. The *high input costs incurred under conventional farming* emerged as the third leading push factor, cited by 67.78% of respondents. Conventional practices often demand greater quantities of fertilizers, pesticides, and other inputs, significantly increasing production costs. This economic burden encourages farmers to explore more cost-efficient precision farming alternatives. Another notable factor was the *poor quality and low market price of produce under conventional methods*, reported by 52.22% of the user farmers and ranked fourth. Farmers noted that the mass availability of produce during peak seasons, typical of conventional practices, leads to market saturation and lower prices, making it less profitable. Lastly, *environmental degradation resulting from conventional farming techniques* was recognized by 37.03% of respondents and ranked fifth. This concern stems from the overuse of agrochemicals and unsustainable practices that harm soil and water health. These findings suggest that the adoption of precision farming technologies is not only driven by the potential for increased yield and efficiency but also by the growing difficulties and unsustainability associated with traditional farming methods. Addressing these push factors through innovation and education could accelerate the transition toward modern, technology-driven agriculture. The findings of the study are in line with Gabriel (2014)

**Table 3: Distribution of user farmers on the basis of their response to push factors for adoption (n=90)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl. No.** | **Push factors for adoption** | **Frequency (f)** | **Percentage (%)** | **Rank** |
| 1 | Non availability of skilled labour required for conventional technologies.  | 76 | 84.44 | 1 |
| 2 | Low yield associated with conventional farming technologies | 69 | 76.66 | 2 |
| 3 | Environmental degradation due to the usage of conventional farming technologies | 33 | 37.03 | 5 |
| 4 | Poor quality and low price of produce received in conventional farming. | 47 | 52.22 | 4 |
| 5 | High cost incurred on inputs in conventional farming technologies  | 61 | 67.78 | 3 |

**Conclusions**

The study reveals that both push and pull factors significantly influence the adoption of precision farming technologies among farmers in Northern India. Pull factors such as higher yield, time and labour savings, government subsidies, improved resource efficiency, possibility of year-round production of seasonal crops and environmental benefits due to adoption of precision farming technologies create strong incentives for adoption of precision farming technologies. On the other hand, labour shortages, low yield associated with conventional methods, high cost incurred on inputs in conventional farming, poor quality produce and environmental concerns over sustainability push farmers toward modern practices. Adoption remains limited among smallholders due to infrastructural and financial barriers, indicating the need for more targeted interventions. With concerted efforts from stakeholders, precision farming technologies can contribute significantly to the modernization and growth of the Indian agricultural sector.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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