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FEASIBILITY OF PRECISION FARMING TECHNIQUES IN INDIA

Aarif Mohammad Khan* and Uzma Khan**

Abstract: *Precision Farming (PF) is a bridge that connects sustainability with enhanced productivity, where natural resource productivity is effectively and efficiently maintained. The primary aims of PF are to increase efficiency, improve environmental performance which eventually leads to increase profitability.*

This paper is based on the primary survey conducted in two districts of Tamil Nadu in the end of the year 2012 on 114 farmers in which the regression findings of socio-demographic profiles of the farmers like education, social category and number of working members in the family etc. will try to identify the factors that are responsible for the adoption of PF in India.

Keywords: *Precision Farming (PF).*

INTRODUCTION

The Green Revolution in India made a considerable progress which made India self- sufficient by enhancing the agricultural productivity during 1960's to 1980's. This success was achieved with the modernization of agricultural inputs use (fertilizers). But still the blanket recommendations of fertilizers for adoption over larger areas are in vogue. These blanket recommendations are no more useful to enhance productivity gains, which were witnessed earlier. Now, to enhance growth rate in productivity, Precision Farming (PF) technology will have to be adopt because PF technologies is a link that connects sustainability with enhanced productivity, where natural resource productivity is effectively and efficiently maintained.

Precision farming is a set of technologies, these technologies can be bundled to form various multiple technology-based farm management systems that provide sit*e*-specific information to assess variability in both crop requirements and natural resources (*e.g.*, soil and water) across an entire field (*e.g.*, Barnes *et al.*, 1996; Isgin *et al.*, 2008; Pinter *et al.*, 2003; Tenkorang and Lowenberg-DeBoer 2004).

* Asst. Prof. in Saint Kabir Institute of Technology and Management, Aligarh.
** Asst. Prof in Prince Sattam Bin Abdul Aziz University, KSA.

Geo-referenced information about crop and soil requirements and production inputs can be used to develop variable rate management plans (*e.g.*, Darr *et al.*, 2003; Fischer 2007; Muzzi 2004; Walton *et al.*, 2010a). Variable rate input application technologies (VRT) can help farmers apply economically optimal rates of inputs across a field which may reduce variable costs, increase revenues by increasing crop yields, and decrease the environmental risks associated with crop production by reducing input requirements such as nitrogen fertilizer (*e.g.*, Bongiovanni and Lowenberg-DeBoer 2004; Bullock, Lowenberg-DeBoer, and Swinton 2002; Roberts, English, and Mahajanashetti 2000; Roberts *et al.*, 2002; Torbett *et al.*, 2007; Velandia *et al.*, 2010;Watson *et al.*, 2005; Yu *et al.*, 2000).

As compared to the developed countries, the development and adoption of precision farming in India is a sluggish process. The primary goals of PF are to increase efficiency, improve environmental performance, and eventually both will lead to increase profitability. On the other hand, increasing yield, lowering input cost, enhancing crop quality and lowering production risk are some of the few factors which will also contribute to the increase in profitability while field efficiency can be improved by performing at the right time and at the right place (by applying the right amount of inputs at the right time, at the right place provides environmental protection without compromising crop yields). Therefore, it is a comprehensive approach which covers all facets of crop production such as tilling, planting, scouting, harvesting, inputs application and post-harvest processing (Ehsani and Durairaj, 2002).

ADOPTION PATTERN

The adoption process for precision farming is difficult to predict because it is not a single technology but/rather a suite of management strategies, technologies, and practices used to improve agricultural decision making that can be chosen in many different combinations of products and services. Farmers will use them in various combinations depending on variations in geography, production systems, and the farmers themselves.

Impact of Precision Farming Technologies

Precision farming (PF) technologies may decrease field-average input application and increase field-average yield to increase profit, and decrease negative environmental impacts of crop production by using inputs more efficiently (Gandonou *et al.*, 2004; Griepentrog and Kyhn 2000; Lambert and Lowenberg-DeBoer 2000; Larkin *et al.*, 2005; Lowenberg-DeBoer 1996; Lund, Christy, and Drummond 1999; Rains and Thomas 2000; Rejesus and Hornbaker 1999; Swinton and Lowenberg-DeBoer 1998; Yu *et al.*, 2000).

Profitability

Lowenberg-DeBoer (1996) mentioned that the profitability from the use of PF technologies was difficult to measure because some costs are often omitted such as human capital costs. In addition, Lambert and Lowenberg-DeBoer (2000) summarized the profitability of using PF from higher yield and/or higher net revenue. This summary included several research efforts described below. Cattanach, Franzen, and Smith (1996) and Swinton and Lowenberg-DeBoer (1998) found that the use of PF was profitable for crops from higher yield. In addition, the results of Barnhisel *et al.*, (1995), Bauer and Mortensen (1992), Clay *et al.*, (1999), Finck (1997) and Yu *et al.*, (2000) found that PF had higher net revenue than the use of other technologies. The implication of higher yield and net revenue might help farmers to increase profits by utilizing precise information from PF technologies within a field (Rains and Thomas 2000). Lower input costs are another factor whereby profits can be increased from PF use. Hayes, Overton, and Price (1994) who studied the feasibility of sit*e*-specific nutrient and pesticide applications found that the fertilizer cost within the fields were reduced from using VRT, implying that the fields might gain more revenues or profits.

Tenkorang and Lowenberg-DeBoer (2004) reviewed literature about profitability of PF technologies and concluded that using PF could have positive or negative effects on net return. For example, Tenkorang and Lowenberg-DeBoer (2004) concluded that the studies of Carr *et al.*, (1991), Copenhaver *et al.*, (2002), Oklahoma State University (2003) and Seelan *et al.*, (2003) found that the use of remote sensing to apply fertilizer, insecticide and/or growth regulator increased average return in crop production. On the other hand, Larson *et al.*, (2004), White, Bethel, and Gress (2002) and White and Gress (2002) reported that the use of aerial imagery produced negative average returns. Some studies found positive net return because they might not take the cost of images, the cost of field operations (*e.g.*, labor) and so on into account, but the studies with the negative net revenue did.

Input Application

Fertilizer, pesticide, herbicide, growth regulators and harvest aids are chemical inputs typically used in cotton production (Rains and Thomas 2000). Griepentrog and Kyhn (2000) found that Variable Rate Technology (VRT) reduced nitrogen application by 36% while maintaining high yields. Also, Ehsani, Schumann, and Salyani (2009) studied VRT in Florida citrus, the results of their study showed 30% reductions in chemicals and 40% reductions in fertilizers applied from using VRT.

Haneklaus, Schroeder and Schnug (1999) found that phosphorous fertilizer application was decreased from the use of VRT. Nordmeyer, Hausler, and Niemann (1997) studied the sit*e*-specific herbicide management and summarized that the use of herbicide in cereal production decreased from the use of VRT. Torbett *et al.*, (2007; 2008), who studied the importance of PF technologies for improving phosphorus (P), potassium (K), and nitrogen (N) application in cotton production, found that grid or management zone soil sampling, and on-th*e*-go sensing were PF technologies that increased the perception of farmers that the use of PF would reduce P, K, and N applications.

Environmental Impact

Lowenberg-DeBoer (1996) mentioned that the environmental impacts from using PF were difficult to systematically and quantitatively measure. Larkin *et al.*, (2005) mentioned that the reduction in input use and input loss to the environment can be implied from farmer perceptions of improvements in environmental quality. The results of Larkin *et al.*, (2005) explained that on*e*-third of PF adopters thought that the use of PF technologies improved environmental quality. Rejesus and Hornbaker (1999), who evaluated the economic and environmental effects of alternative pollution-reducing nitrogen management practices in central Illinois, found that the use of VRT reduced the pollution discharged into the environment from decreasing fertilizer application. Gandonou *et al.*, (2004) studied PF technology and its impact in reducing environmental damage in cotton production in developing country. Results suggested that the use of fertilizers was slightly reduced within a corn-cotton crop rotation. Less fertilizer application might imply decreased environmental damages within fields.

Factors Influencing Adoption of PF Technologies

Many researchers have investigated the factors influencing the decision to adopt PF technologies (*e.g.*, Arnholt, Batte, and Prochaska 2001; Daberkow and McBride 1998; Daberkow and McBride 2003; Feder and Slade 1984; Khanna 2001; Khanna, Epouhe, and Hornbaker 1999; Mooney *et al.*, 2010; Roberts *et al.*, 2002; Roberts *et al.*, 2004a, 2004b; Swinton and LowerbergDeBoer 2001). The principal factors influencing the adoption of PF technologies are operator characteristics, farm physical attributes, sources of information, and financial and structural characteristics of the farm business.

Examples of operator characteristics include age, formal education, years of farming experience, and computer literacy (*e.g.*, Daberkow and Mcbride 1998; Fernandez-Cornejo, Beach, and Huang 1994). Examples of farm physical attributes include farm size, owned or rented land (Banerjee *et al.*, 2008), and sub-field variability in pH, organic matter, soil type and texture, topography, and drainage that influence crop yields (*e.g.*, Daberkow and Mcbride 1998). Crop consultants, input suppliers, and equipment dealers with expertise in PF services provide information that influences PF technology adoption by farmers (*e.g.*, Velandia *et* *al.*, 2010; Wolf and Nowak 1995). The financial position of the farm also influences PF adoption decisions (*e.g.*, Daberkow and Mcbride 1998). Additionally, profitability and environmental benefits are correlated with the PF technology adoption decision (*e.g.*, Batte and Arnholt 2003).

ECONOMIC FEASIBILITY OF PRECISION FARMING IN INDIA

Feasibility of Precision Farming depends on field variability, crop value, and economies of scale. Precision farming implies a management strategy to increase productivity and economic returns with a reduced impact on the environment, by taking into account the variability within and between fields. Variability description, variabl*e*-rate technology and decision support systems are the key technologies for precision farming. Precision farming on a regional level is one way to apply this approach to small-farm agriculture. It may not only improve farm management, but may also promote the development of rural areas (Kamble, 2005).

1. On the one hand there are depletions of ecological foundations of the agro-ecosystems, as reflected in terms of increasing land degradation, depletion of water resources and rising trends of floods, drought and crop pests and diseases. On the other hand, there is imperative socio-economic need to have enhanced productivity per units of land, water and time.
2. At present, 3 ha of rain fed areas produce cereal grain equivalent to that produced in 1 ha of irrigated. Out of 142 mha. Net sown areas, 79 mha are under rain-fed agriculture in the county.
3. From impartiality point of view, even the record agricultural production of more than 200 Mt is unable to address food security issue in future. A close to 80 Mt food grains in the storehouses of Food Corporation of India (FCI) by the end of June 2012 is beyond the affordability and access to the poor and marginalized in many pockets of the country.
4. Globally, there are challenges arising from the Globalization especially the impact of WTO regime on small and marginalized farmers.
5. Some other unforeseen challenges could be anticipated global warming scenario and its possible impact on diverse agro-ecosystems in terms of alterations in traditional crop belts, micro-level perturbations in hydrologic cycle and more uncertain crop-weather interactions etc.

Trends in Precision Farming in India

The principle technology should be efficient, practical, cost effective and free from pollution. The sustainability factor should be looked at the ability of agricultural land to maintain acceptable levels of production over a long period of time, without degrading the environment. But the main drawback which the developing countries facing especially India is that PF techniques is not properly adopted by the Indian farmers as they are financially weak and have small land size holdings. Still there is a hope that progressive Indian farmers, with guidance from the public and private sectors, agricultural associations, will adopt it in a limited scale for demonstrations as the technologies shows potential for raising yields and economic returns with minimizing environmental degradation.

PA has been identified as one of the main thrust areas by the Working Groups (WGs) of India-US Knowledge Initiative on Agriculture (KIA). It is expected that PA research will be an important part of the recently launched ambitious agricultural research program, National Agricultural Innovation Project (NAIP), which will focus on innovations in agricultural technology with the announced budget of US$ 285 million. Tamil Nadu State Government has sanctioned a scheme named ''Tamil Nadu Precision Farming Project" to be implemented in Dharmapuri and Krishnagiri districts covering an area of 400 ha. High value crops such as hybrid tomatoes, capsicum, babycorn, white onion, cabbage, and cauliflower are proposed to be cultivated under this scheme. As a future extension plan, the same scheme will be implemented in six more districts of Tamil Nadu. The scheme will be implemented in an area of 100 ha from each district. With the Project Directorate for Cropping Systems Research (PDCSR), Modipuram and Meerut (Uttar Pradesh state) in collaboration with Central Institute of Agricultural Engineering (CIAE), Bhopal also initiated variable rate input application in different cropping systems. With the Space Application Center (ISRO), Ahmedabad has started experiments in the Central Potato Research Station farm at Jalandhar, Punjab, to study the role of remote sensing in mapping the variability with respect to space and time (Shanwad U.K., Patil, V.C., and Gowda, H.H., 2006).

Development of specialized centers and scientific data- bank is a well-known pr*e*-requisite for PA. The PA technology is started to be developed and disseminated in a regionally differentiated manner through 17 Precision Farming Development Centers (PFDCs) located in different parts of India (Dugad S.V., and Sudhakar M.S., 2006). PFDCs are working for the popularization of PA and hi-tech applications to achieve increased production in addition to imparting training to a large number of farmers. But all these PFDCs mainly concentrate on precision irrigation water management. As an example of collaborative effort of private and Govt. agencies, a new precision farming centre has been established by MSSRF (M.S. Swaminathan Research Foundation – a non-profit trust) at Kannivadi in Tamil Nadu with financial support from the National Bank for Agriculture and Rural Development (NABARD). This Precision Farming Centre receives the help of Arava R&D Centre of Israel and works with an objective of poverty alleviation by applying PA technologies.

To explore the potential of application of IT in the agro- sector, Tata Chemicals Ltd., a private sector, has been started with an objective of providing the farmers with infrastructure support, operational support, coordination and control of farming activities and strategic support. Tata Kisan Kendra has been replicated successfully in the states of Uttar Pradesh, Haryana and Punjab. The project has been claimed to be scalable and replicable. Private sectors such as Indian Tobacco Company (ITC) have established '*e*-choupals', which are village internet kiosks that enable access to information on weather, market prices and scientific farm practices, crop disease forecasting system and expert crop advice system. Nearly 1200 '*e*-choupals' have already been developed across four states of India. Region-specific and crop-specific (such as soybean, coffee, wheat, pulses, and rice) '*e*-choupals' are under development to provide more specific information to the poor farmers of all remote areas of the country (Singh, M., Singh, G., 2006).

A good amount of research has been initiated on plant-need-based real-time N management for rice. LCC is becoming an effective low-technology PA tool for the need-based N management of rice grown in small farms of India. In 107 on-farm experiments conducted on rice, the average yield recorded in LCC-based real-time N management and that obtained by following farmer's practice were identical. On average, about 40 kg Nha^{-1} less fertilizer was applied following the need-based fertilizer management as compared with the farmer's practice. In 48 on-farm experiments conducted at different locations in north-western India, LCC-based N management was tested on rice varieties commonly grown by small farmers. Savings of 16–43 kg N ha^{-1} were observed for seven different rice cultivars by applying N using LCC rather than by following the farmer's practice (Singh, B., Singh, Y., Singh, M., 2006). The popularity of LCC for rice grown in small farms has been documented in many literatures. Islam *et al.*, reported that about 47% and 28% of farmers of the intervention and control villages, respectively, adopted LCC during a farmer-participatory experiment in West Bengal, India. They also found that the first time adopters experimented with LCC on about half of their rice lands, which rapidly increased with experience, and reached 97% in the third year. Adoption of LCC saved N by 19.4–21.0%. They predicted that the combined effects of reduced N and insecticide use on the environment protection might be enormous, provided large areas were adopted. IRRI, Philippines, reported that more than 5000 pieces of low-cost LCC were distributed or sold to Indian rice farmers (Singh, R.B. *et al.*, 2002). This is an example of the fact that PA has started to find its own way of penetrating small Indian farms.

Experience of field level experiments is an indispensable part of PA. Laser land levelling was used as a tool of PA to increase the input-use-efficiency. After precise levelling of fields, the irrigation efficiencies increased significantly. The average application efficiency of 65%, storage efficiency of 70% and water distribution efficiency of 80% were achieved after laser levelling. The yield of rice crop also increased, by 15–20% in laser-levelled fields. Precision land levelling increased the production of pigeon-pea crop by 32% (Chandhuri, D. *et al.*, 2006).

The development of a computer model, DSS, a region- specific expert system, for agriculture can be indirectly helpful to depict the path of PA revolution in India. A computer-aided software named 'CROP9 -DSS' has been developed, which will aid as a DSS for calibrating water and fertilizer requirement, crop protection and identification of implements for the leading crops of the state of Kerala (Ganeshan, V., 2006). Agro-Climatic Planning and Information Bank (APIB) is under development, which is a concept-demonstration project executed by ISRO and the Planning Com- mission towards establishment of a single window access to all agricultur*e*-related information and decision support to users of agricultural and allied sectors (Padmavathi, M., and Gowda H.H., 2006).

A large amount of already done work on GIS and remote sensing application, such as the use of GIS for soil data analysis (Ramakrishnan, S.S., and Guruswami, V., 2006), crop discrimination in salt-affected soils by IRS 1A LISS II satellite data, performance evaluation of an irrigation project using IRS 1A LISS II (Sharma, R.K. *et al.*, 2006) and IRS–1C/1D LISS III data, GIS and GPS (Chakraborti, A.K. *et al.*, 2006), can be extremely helpful to develop trained manpower pool for PA. A study has been carried out with 28.7 thousand ha of potato growing area of Bardhaman district of West Bengal state by using IRS 1C WiFS (188 m resolution) and IRS 1C LISS -III (23 m resolution) data. The GIS map helped in finding the optimized locations of future cold storages to meet the needs of small and marginal farmer's also (Ray, S.S. *et al.*, 2006).

USE OF PRECISION TECHNIQUES AMONG FARMERS (SURVEY)

Adopting some of the components of precision farming technologies could help in improving the current level of production practices, alleviate poverty by increasing profitability and subsequently, enable farmers to better cope with a changing institutional environment.

In this survey it was found that every farmers of these districts was using the Micro Irrigation Systems (the systems in which water is directly applied to the root zone of the plants, were introduced mainly to prevent the excessive wastage of water in the conventional systems of irrigation, like flood irrigation), as an essential component used in the name of precision farming. This system's prime aim is to reduce water consumption in the field. Apart from this, the micro irrigation systems helps to reduce the amount of inputs used, the electricity consumption, fertilizer use, and labour requirement. Also, the micro irrigation systems are known to help increase the yield of the land, *i.e.* the same land can provide higher yields if micro-irrigation systems are used, as compared to the flood irrigation techniques.

All the other techniques of precision farming like GPS, GIS, RS, Yield Monitor (YM) and VRA guided with GPS are not in practice in developing countries especially India. With limitation in facilities, only a few simpler tools of the precision farming technologies is being practiced to boost the productivity and that starts happening in many states across India.

The few simple tools that are being adopted are as follows (http://www.scribd.com/doc/27774940/Assignment-205-Precision-Farming):

1. Soil analysis for critical level of nutrients and also soil reclamation for problem areas.
2. Applying fertilizers according to the crop requirement and infield variability over smaller plots not considered.
3. Chiselling to break hard pans, partial mechanization of larger holdings for raising broad bed and furrows, weeding inter row spacing and mechanical harvesting in some crops.
4. For wide spaced crops, fruits and vegetables installation of drip irrigation systems.
5. For high value crops, fertigation with high cost water soluble fertilizers is also gaining momentum. There are so many success stories across India. The drip fertigation technology adoption alone has seen a fivefold increase in many important commercial, horticultural and agricultural crops. Many farmers opined that cost for irrigation, fertilizer application, weeding and harvesting has come down drastically after switching over to drip fertigation method.
6. Use of organic manures and adoption of integrated management practices in irrigation, nutrients, weeds, insects and pathogens seem to reduce costs increase yield and safeguard environment. Large scale adoption of PF in future will have pronounced impact on the food scenario of the country but this may not happen. Exposing the fellow farmers for motivation to switch over to this newer technology by forming commodity and activity based groups can yield definite results in the production enhancement.

FACTORS AFFECTING ADOPTION OF PRECISION FARMING

In the present existing situation, the potential of precision agriculture in India is limited by the lack of appropriate measurement and analysis techniques for agronomically important factors. High accuracy sensing and data management tools must be developed and validated to support both research and production.

The limitation in data quality/availability has become a major obstacle in the demonstration and adoption of the precision technologies. The review of the past studies showed that the lack of finance and credit facilities were the most important obstacle for non-adoption of precision farming, as obtaining credit was a difficult process because farmers could not produce collateral security.

The adoption of precision agriculture needs combined efforts on behalf of scientists, farmers and the government. The following methodology could be adopted in order to operationalize precision farming in the country (http://www.scribd.com/doc/27774940/Assignment-205-Precision-Farming).

1. Creation of multidisciplinary teams involving agricultural scientists in various fields, engineers, manufacturers and economists to study the overall scope of precision agriculture.
2. Formation of farmer's co-operatives since many of the precision agriculture tools are costly (GIS, GPS, RS, etc.).
3. Government legislation restraining farmers using indiscriminate farm inputs and thereby causing ecological/environmental imbalance would induce the farmer to go for alternative approach.
4. Pilot study should be conducted on farmer's field to show the results of precision agriculture implementation.
5. Creating awareness amongst farmers about consequences of applying imbalanced doses of farm inputs like irrigation, fertilizers, insecticides and pesticides.
6. Some farm holdings are fragmented and even minimal mechanization is not possible.
7. The soil and other analytical facilities are also a limiting factor.
8. Culture and perceptions of the users - High tech cultivation practices are not accepted by farmers in developing countries because the farmers are largely resource poor.
9. Most of the inputs namely water soluble fertilizers, hybrid seeds, annual fruit seeds and seedlings are being used at high costs and only a few farmers can afford the costs involved.
10. The existing post harvesting facilities and market chains are at stake and not in a position to store or transport the produce.
11. High cost of sophisticated machines/equipments also acts as a limiting factor.
12. Small farm size.
13. Lack of success stories.

14. Heterogeneity of cropping systems and market imperfections.
15. Land ownership, infrastructure and institutional constraints.
16. Lack of local technical expertise.
17. Knowledge and technical gaps.
18. Data availability, quality and costs.

REGRESSION MODEL RESULTS ON THE ADOPTION OF PRECISION FARMING TECHNOLOGY

Background of the Study

The precision agriculture adoption literature shows that some demographic factors can affect adoption. Studies have indicated age, farming experience, education level of farm owners, off-farm employment, farm size and crops grown influence the adoption of precision agriculture technology (Daberkow and McBride, 2003).

Other Variables

The variables to explain the adoption pattern are based on human capital theory, farm and production characteristics, and other variables used in adoption literature. Education and farming experience are measures of human capital that reflect the ability to innovate ideas. We expect that human capital has positive influence in the decision to adopt a new technology. Previous studies (Paxton *et al.*, 2010; Roberts *et al.*, 2004; Velandia *et al.*, 2010; Walton *et al.*, 2010) have shown that age, income, farming experience are widely accepted human capital variable that affect adoption decisions. Most of these studies have shown that age has negative influence on technology adoption (Soule *et al.*, 2000; Logsdon, 2006).

Education Level

Young farmers are educated and willing to innovate and adopt new technologies that reduce time spent on farming (Mishra *et al.*, 2002). Therefore, education and farming experience positively influence technology adoption because farmers with those attribute are exposed to more ideas and have more experience making decisions and effectively using the information (Caswell *et al.*, 2001). Early adopters of technology have higher education level than later adopters (Rogers, 1983). While other studies indicates that information technology adoption is different among agricultural producers with different level of education (Hoag *et al.*, 1999).

Farm Size

Farm characteristics are important variable for understanding a farmer's decision to adopt (Prokopy *et al.*, 2008). If a farmer perceives that the adoption of technology would be profitable prior to making decision, he will be likely to adopt precision agriculture (Napier *et al.*, 2000; Roberts *et al.*, 2004). We also use financial and location variables as reasons for precision agriculture technology adoption.

Publications

University publications are helpful to cotton producer to obtain precision farming information. Extension services convey information about university research and publication that help farmers to make informed decision which can influence profitability (Hall *et al.*, 2003). Producers tend to use multiple sources of information to increase their knowledge about precision agriculture (Velandia *et al.*, 2010). Therefore, information is expected to be positively related to technology adoption because exposure to knowledge about precision agriculture leads some farmers to adopt new technology (Rogers, 2003).

Environmental

Use of excessive chemical fertilizer could leach or runoff causing water pollution. Thus, use of manure could be an important factor in choice of precision technology that reduces water pollution. If a farmer perceives that fertilizer efficiency can be increased by adopting PF technologies, he would adopt those (Torbett *et al.*, 2007).

Although these above studies provide some reasons for the adoption of PF technologies, there could be other possible variables affecting farmers decision making process. Many farmers are uncertain to use available technology due to environmental regulations, public concern, and economic gains from reduced inputs and improved managements, and hence these factors determine success of precision farming (Zhang *et al.*, 2002)

OUTCOMES OF THE REGRESSION MODEL

The results on coefficient estimate, standard errors, Wald statistics, significance levels and odd ratio for the Parameters of the Logistics Regression Model on factors affecting the adoption of precision farming is presented in table. A logistic regression analysis was conducted to predict adoption of precision farming for 114 farmers using their demographic and farm characteristic detail as predictors. A test of the full model against a constant only model was statistically significant, indicating that the predictors as a set reliably distinguished between adopter and non-adopter of the precision farming (chi square = 112.542, $p < .000$ with $df = 10$). Nagelkerke's R^2 of 0.852 indicated a strong relationship between prediction and grouping. Overall correct prediction success was 93.0% (86.4% for decline and 97.1% for accept).

Table 1
Regression results – factors affecting adoption of precision farming

Independent variables	Parameter detail	B	S.E.	Wald	Df	Sig.	Exp(β)
	Dependent variable *Adoption of precision farming (Yes = 1, Otherwise = 0)*						
AGE	Farmer's age (< 35 years = 1, Otherwise = 0)	–0.462	.940	0.241	1	.623	0.630
EDU	Farmer's education (High School and above = 1, otherwise = 0)	3.227***	1.058	9.303	1	.002	25.210
SOC	Social category of farmers (General = 1, otherwise = 0)	2.241*	1.201	3.485	1	.062	9.406
FMSIZE	Family size (> 5 members = 1, otherwise = 0)	–1.979	1.213	2.660	1	.103	.138
WRKM	Number of working members (> 2 members = 1, otherwise = 0)	3.639*	2.006	3.290	1	.070	38.049
INCM	Monthly household income (> Rs. 15000 = 1, otherwise = 0)	3.138***	.991	10.030	1	.002	23.055
LAND	Landholding size (> 2 hectares = 1, otherwise = 0)	3.547**	1.427	6.182	1	.013	34.710
ICT	Adoption of ICT (Yes = 1, otherwise = 0)	2.205***	1.172	3.541	1	.060	9.067
HVC	Growing high value crops (Yes = 1, otherwise = 0)	0.826	1.336	0.383	1	.536	2.285
Constant		–5.793	1.684	11.828	1	.001	0.003
	–2 Log likelihood	40.841					
	Cox and Snell R Square	0.623					
	Nagelkerke R Square	0.846					
	Chi-square	111.215***					
	Correct prediction (%)	93					

***significant at the 0.01 level, **significant at the 0.05 level, *significant at the 0.10 level

Results of regression analysis indicate that among the factors on socio-demographic profiles of the farmers, education, social category and number of working members in the family are more likely to affect the adoption of precision farming techniques.

The age prediction shows β value as –0.5 which suggests inverse relationship between age of the farmers and adoption of precision farming. However, the regression coefficient for age is statistically insignificant. This implies that age of the farmer is less likely to affect the adoption of precision farming techniques. The educational factor shows β value as 25.2 which reflects that the education above high school contributes 25 times in the adoption of precision farming among farmers which is statistically significant (p = .002) as their EXP (β) value indicates that when education (above High school) is raised by 1 unit (one person) the odds ratio is 25 times as large and therefore literate persons are 25 more times likely to adopt the precision farming.

The social category depicts β value as 2.2 which reveals that the general class contributes 9 times in the adoptions of precision farming among farmers and is statistically significant (p = .062) as their EXP (β) value indicates that when social category (general class) is raised by 1 unit (one person) the odds ratio is 9 times as large and therefore general class are 9 more times likely to adopt the precision farming.

The family size category depicts β value as –2.0 (a negative B value) with a non-significant relationship in the adoption of precision farming technology among farmers (p = .103). Their EXP (β) value indicates that as the family size increases from more than 5 its negative contribution will be 0.1 times in the adoption of precision farming.

The working members depicts β value as 3.6 which reveals that as the working member size increases from two to more than two its contribution reaches 38 times in the adoptions of precision farming among farmers with a significance level of p is equal to 0.07 and their EXP (β) value indicates that when working member is raised by 1 unit (one person) the odds ratio is 38 times as large and therefore working member are 38 more times likely to adopt the precision farming.

The income category depicts β value as 3.1 reveals that as the earn income of the farmers is Rs 15000 per month or more its contribution will be 23 times in the adoptions of precision farming among farmers with a significance value (p = .002) and their EXP (β) value indicates that when income above Rs 15000 per month is raised by 1 unit (one person) the odds ratio is 23 times as large and therefore income are 23 more times likely to adopt the precision farming.

The land holding shows β value as 3.5 reveals that farmer more than 2 hectare of land will contributes 35 times in the adoptions of precision farming among farmers which is statistically significant (p = .013) and their EXP (β) value indicates that when landholding (< 2ha) is raised by 1 unit (one person) the odds ratio is 35 times as large and therefore landholding are 35 more times likely to adopt the precision farming.

The information communication technology depicts β value as 2.2 reveals that farmers willingness to adopt contributes 9 times in the adoptions of precision farming among farmers which is statistically significant (p = .060) and their EXP

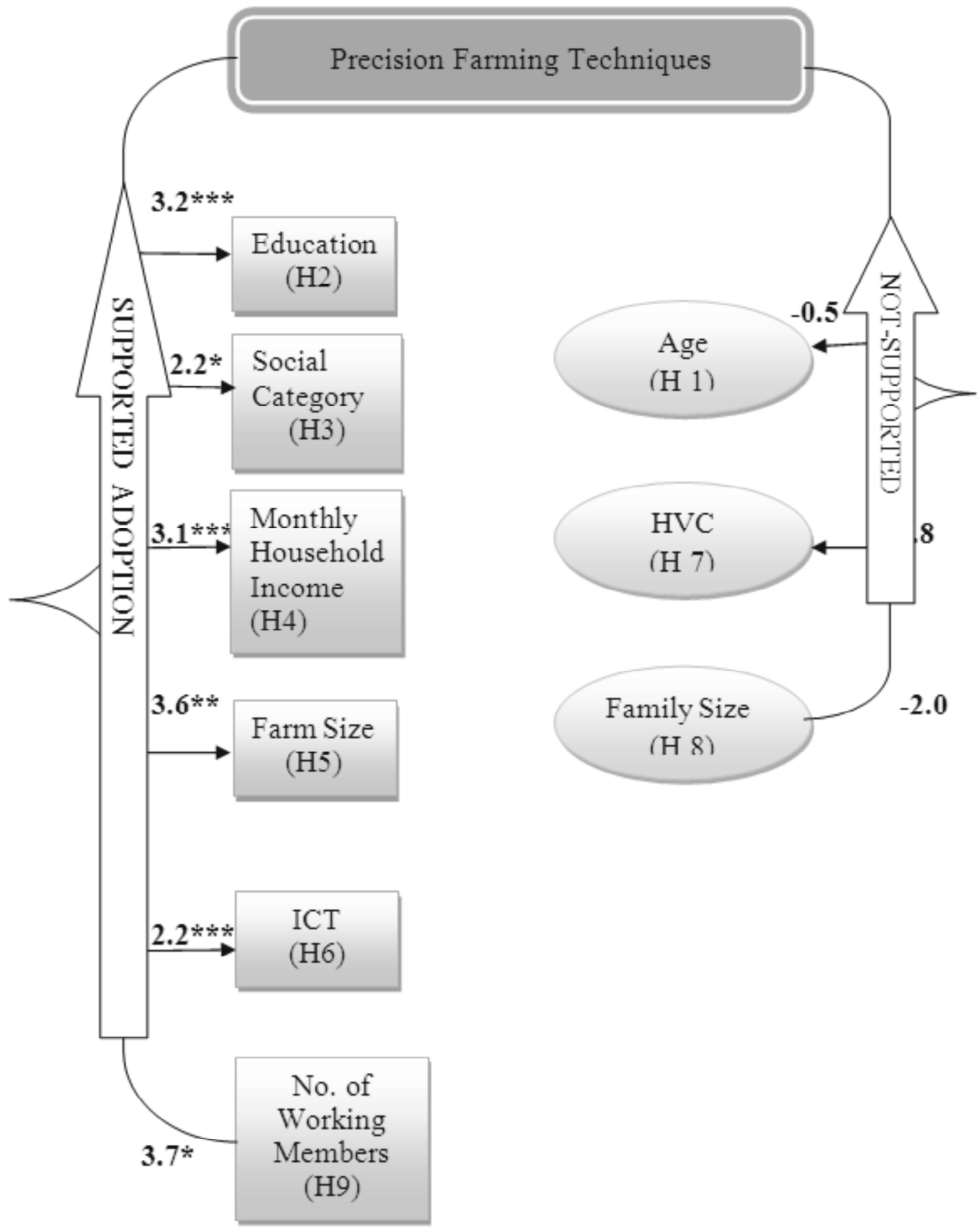

Figure 1: Flow chart on regression model for the adoption of precision farming techniques in India.

(β) value indicates that when information communication technology is raised by 1 unit (one person) the odds ratio is 9 times as large and therefore information communication technology are 9 more times likely to adopt the precision farming.

The high value crop also depicts β value as 0.8 reveals that the farmers adopt high value crops for farming which contributes 2.3 times in the adoptions of precision farming among farmers but it is statistically insignificant (p = .536).

Table 2
Hypotheses and regression results

#	*Hypothesis*	*B*	*Sig./ P level*	*Exp(β)*	*Hypothesis (Support)*
H1	Age negatively influences adoption of precision farming.	–0.462	0.623	0.63	Not Supported
H2	Education level positively influences adoption of PF.	3.227***	0.002	25.21	Supported
H3	Social category positively influences adoption of PF.	2.241*	0.062	9.406	Supported
H4	Monthly household income positively influences adoption of PF.	3.138***	0.002	23.055	Supported
H5	Farm size positively influences adoption of PF.	3.547**	0.013	34.71	Supported
H6	Information and communication technology positively influences adoption of precision farming.	2.205***	0.06	9.067	Supported
H7	High value crop positively influences adoption of precision farming.	0.826	0.536	2.285	Not Supported
H8	Family size negatively influences the adoption of precision farming.	–1.979	0.103	0.138	Not Supported
H9	Number of working members positively influences the adoption of precision farming.	3.639*	0.07	38.049	Supported

***significant at the 0.01 level, **significant at the 0.05 level, *significant at the 0.10 level

OTHER ASPECTS BASED ON PRIMARY DATA ANALYSIS

Other aspects which a researcher faces during farm survey are:

1. Lack of complete knowledge about precision farming technologies among masses because a majority of small farmers were not acquainted about the latest technologies.
2. Precision farming increases production efficiency but in post harvesting, labour is an important factor and due to urbanization and migration there was a scarcity of labour for agricultural operation, as post harvesting of some crops like floriculture is highly labour-intensive technology and operation were time bound, hence farmers faced the dearth of labour especially during stacking and harvesting.

3. The non-precision had a wrong perception about the higher yield from the precise quantity of inputs, thus regarded as a major obstacle to the adoption of precision farming.
4. Other aspects were the lack of water availability and pump efficiency, lack of technical skill, inadequate size of land holdings, mind set, and traditional believes among the masses.
5. Finally, the local market was not big enough to accumulate the huge quantity of output produced through precision farming, so farmers had to negotiate with super markets and this sometimes led to low price and less profits.

CONCLUSIONS

The regression model associated with the precision farming expands our knowledge of precision farming use by examining adoption pattern of farmers towards precision farming technology for water resource management. This, paper helps us to determine factors which influence adoption pattern, other than perceived economic benefits, that are important in making the decision to use precision farming technologies.

Basic drawback of our agricultural farming in India is that many of these technologies used are in an infant stage, and pricing of equipment and services is hard to pin down. Even though some farmers had started to use precision farming methods, majority of the farmers are still not aware about these technologies and also not all farms are suitable to implement precision farming tools. For instance, some growers are likely to adopt it partially; adopting certain elements but not others and thus limit its implications.

Results of our study showed that, the adoption of precision farming technologies in India is a result of multi-dimensional considerations. Extrapolated from the discussion, the adoption of precision farming technologies is positively associated with:

1. Socio-demographic factors (farmers who have higher education level, social category, number of working members), and
2. Farm characteristics factors (farmer's farm size, monthly household income).

Our findings clearly indicated that if both the above factors are promoted among farmers then it will help them to get well equipped with the precision farming technologies. Thus, for effective diffusion of precision farming technologies and their promotion, the above factors should be well targeted.

In successful Green Revolution areas of Punjab, Haryana and Western Uttar Pradesh where farmers are relatively rich and more educated. The precision farming technique for water resource management can become easily popular if it perceived long-term benefits are properly communicated. Government should encourage farmers to adopt precision farming technique for water resource management in these areas by providing necessary help and assistance as well as some financial and tax concession.

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