# Operationalization of Precision Farming in India

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**ABSTRACT:**

*Precision farming* has been the buzzword of agricultural research around the globe in recent times. It is based on the philosophy of **heterogeneity within homogeneity** and requires precise information on the degree of variability for within field management. The aim is to vary the agricultural inputs in response to the varying conditions within the field.

The various attempts that have been made to operationalize precision farming in the West involve the use of intelligent devices like the yield mapper (comprising of a harvester, yield measuring sensor and a GPS), variable rate fertilizer rigs and the satellite imagery to supplement the information on the crop variability at a good spatial resolution as well as temporal resolution. Geographic Information System (GIS) integrates the information from all these devices, which culminates into Precision Farming. This mapping and agricultural machinery are together called the agricultural positioning system. In India also, there has been a lot of discussion about the adoption of this novel technology. Precision farming also features as one of the main research agenda in the tenth five-year plan. But the question which needs to be answered is the feasibility of such a technology in a developing country like India where the average size of operational land holding is only 1.57 hectares and nearly 30 percent of the population lives below the poverty line. The cost of full-fledged agricultural positioning system is around ten to fifteen lac rupees, which is too prohibitive for any type of farmer in the country. Also there needs to be a substantially big landholding for easy movement of big machinery, which is not the case. This ground reality makes the scene just too dismal for any major development at least in the near future.

As part of an attempt to operationalize precision farming in India in the near future, the authors propose to use the existing methodology (***VRT in integration with RS, GIS, and GPS technologies***) with a greater emphasis on sowing seeds at proper spacing. Accuracy of the level of getting the required accuracy in cms by establishing a DGPS network all over India. The authors expect to get a substantial increase in the crop yield in which case the practice can be made operational on a taluk basis using the practice of collective tilling of land and sharing of benefits in the proportion to the size of the landholdings. In addition, the cost analysis of setting up the DGPS network and the benefit it yields with respect to India's GDP is analyzed.

India is yet to reach the lowest level of potential productivity of the high-yielding varieties and if we are to increase our productivity on the global scale, precision farming is a must. The scope of the proposed study is realistic and achievable within the current capabilities of our economy. To conclude, a techno-green revolution which catalyses the economy is the need of this century.

## 1. Introduction:

***"Agriculture is the backbone of the Indian Economy"***- said Mahatma Gandhi five decades ago. Even today, as we enter the new millennium, the situation is still the same, with almost the entire economy being sustained by agriculture, which is the mainstay of the villages. Not only the economy, but also every one of us looks up to agriculture for our sustenance too. Therefore, it is no surprise if agriculture gets the celebrity status in the name of *Precision farming (PF).* In recent times, the researchers in the field have been busy formulating methodologies and fabricating new implements for precision farming. It is here the challenge arises considering the implementation of the technology at various levels in the Global community. The need of the hour is not application of the technology but the adoption of *appropriate technology*, which would suit the particular level of the global community. In India, the farming practices are too haphazard and non-scientific and hence need some forethought before implementing any new technology. It is here that this paper comes out with a cost-benefit analysis to prove that precision farming is possible in India.

Applications of agricultural inputs at uniform rates across the field without due regard to in-field variations in soil fertility and crop conditions does not yield desirable results in terms of crop yield. The management of in-field variability in soil fertility and crop conditions for improving the crop production and minimizing the environmental impact is the crux of precision farming. Thus, the information on spatial variability in soil fertility status and crop conditions is a pre-requisite for adoption of precision farming. Space technology including global positioning system (GPS) and GIS holds good promise in deriving information on soil attributes and crop yield, and allows monitoring seasonally- variable soil and crop characteristics, namely soil moisture, crop phenology, growth, evapotranspiration, nutrient deficiency, crop disease, and weed and insect infestation, which, in turn, help in **optimizing inputs and maximizing crop yield and income**.

Though widely adopted in developed countries, the adoption of precision farming in India is yet to take a firm ground primarily due to its unique pattern of land holdings, poor infrastructure, lack of farmers' inclination to take risk, socio-economic and demographic conditions. The aim of this paper is to suggest measures for the implementation of this novel technique in the country with a greater emphasis on the systematic approach towards its operationalisation.

## 2. Objectives

1. To explain the feasibility of precision farming technology with emphasis on seed spacing, tillage, etc.
2. To set up a DGPS network all around the country and achieving few centimeters accuracy for the purpose of Site-Specific Management (SSM) in Precision Farming .
3. To analyze the cost and benefit in terms of Indian farmer's income-expenditure.

## 3. Precision Farming

The conventional agronomic practices follow a standard management option for a large area irrespective of the variability occurring within and among the field. For decades now, the farmers have been applying fertilizers based on recommendations emanating from research and field trials under specific agro-climatic conditions. Since soil-nutrient, characteristics vary not only from one region to another, but also from field to field (Ladha et al., 2000). Even within a field, there is a need to take into account such variability while applying fertilizers to a particular crop. Consideration of in-field variations in soil fertility and crop conditions and matching the agricultural inputs like seed, fertilizer, irrigation, insecticide, pesticide, etc. in order to optimize the input or maximizing the crop yield from a given quantum of input, is referred to as precision farming or precision agriculture or precision crop management.

The term "*precision farming*" means carefully tailoring the soil and crop management to fit the different conditions found in each field. It is defined as the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production. (Pierce and Nowak, 1999). It is also referred to as "*prescription farming*", "*site specific farming*" or "*variable rate technology*."

By catering to this variability, called precision farming, one can improve the productivity or reduce the cost of production and diminish the chance of environmental degradation caused by excess use of inputs (Pierce and Nowak, 1999). Thus, mapping and analysis of within field variability is an essential input for precision crop management. Thus, PF involves acquiring the variations in crop or soil properties, mapping, and analyzing the variations, adopting suitable management techniques to maximize the yield. Farmers have been applying fertilizers based on recommendations emanating from research and field trials under specific agro-climatic conditions, which have been extrapolated to a regional level. Since soil nutrient characteristics vary not only between regions and between farms but also from plot to plot (Ladha et al., 2000), and within a field or plot, there is a need to take into account such variability while applying fertilizers to a particular crop. Consideration of in-field/plot variations in soil fertility and crop conditions and matching the agricultural inputs like seed, fertilizer, irrigation, insecticide, pesticide, etc. in order to optimize the input or maximizing the crop yield from a given quantum of input, is referred to as precision farming or precision agriculture or precision crop management.

The information for variability map can be obtained from soil tests for nutrient availability, yield monitors for crop yield, soil samples for organic matter content, information in soil maps, or ground conductivity meters for soil moisture (Mulla, 1997). Generally, the fields are manually sampled along a regular grid and the analyzed results of the samples are interpolated using geostatistical techniques. These techniques are time consuming, labour intensive and in many cases destructive especially, for agricultural situation in India. With small size of landholdings and low income of farmers, the adoption of this methodology in its present form is not feasible. Various workers (Hanson et al., 1995, Taylor et al., 1997, Moran et al, 1997) have shown the advantages of using remote sensing technology to obtain spatially and temporally variable information for precision farming. In an earlier work, Ray et al. (2001) have shown the usefulness of IRS merged data in mapping the variability.

**4. Components of precision farming**

1. Remote Sensing
2. GIS
3. DGPS
4. Variable rate Applicator

**4.1 Remote Sensing**

This is for Data acquisition of the farms to find the soil, vegetation and other parameters that are amenable for remote sensing. Remote sensing techniques play an important role in precision farming by providing continuous acquired data of agricultural crops. Remote sensors image vegetation, which is growing on different soil types with different water availability, substrate, impact of cultivation, and relief. These differences influence the state of the plants and cause heterogeneous regions within single fields. Hence, the heterogeneous vegetation acts as an interface between soil and remote sensing information, because vegetation parameters describing the state of the plants can be deduced from remote sensing imagery. The analysis of the variability occurring within the field was carried out by measuring soil and plant parameters through conventional methods as well as through spectral techniques using ground truth spectroradiometer (350-1800 nm) and satellite data. Ray et al. (2001), in general, have reviewed by Moran et al. (1997) and for Indian conditions the potentials of remote sensing in providing information required for precision farming.

**4.2 Geographical information system**

The Geographic Information System (GIS) contributes significantly to precision farming by allowing presentation of spatial data in the form of a map. In addition, GIS forms an ideal platform for the storage and management of model input data and the presentation of model results, which the process model provides.

**4.3 DGPS**

***'Do the right thing, in the right place and in right time'***

– This is where GPS comes into picture. In addition, the accuracy, which is the important factor in PF, demands for DGPS (Differential Global Positioning System). GPS makes use of a series of military satellites that identify the location of farm equipment within a meter of an actual site in the field. The value of knowing a precise location within inches is that:

(1) Locations of soil samples and the laboratory results can be compared to a soil map,

(2) Fertilizer and pesticides can be prescribed to fit soil properties (clay and organic matter content) and soil conditions (relief and drainage),

(3) Tillage adjustments can be made as one finds various conditions across the field, and

(4) One can monitor and record yield data as one goes across the field.

The Global Positioning System (GPS) technology provides accurate positioning system necessary for field implementation of variable rate technology (VRT). The

Internet makes possible the development of a mechanism for effective farm management using remote sensing.

**4.4 Variable Rate Applicator:**

The variable rate applicator has three components:

1. Control computer
2. Locator and
3. Actuator

The control computer coordinates the field operation. It has a map of desired activity as a function of geographic location. It receives the equipment's current location from the locator, which has a GPS in it, and decides what to do based upon the map in its memory or data storage. It then issues the command to the actuator, which does the input application (Ravi and Jagadeesha, 2002).

**5. Practical problems in Indian agriculture**

Precision Agriculture has been mostly confined to developed countries. Reasons of limitations of its implementation in developing countries like India are:

***a) Small land holdings,***

***b) Heterogeneity of cropping systems and market imperfections,***

***c) Lack of technical expertise knowledge and technology (India spends only 0.3% of its agricultural Gross Domestic Product in Research and Development)***

***d) High cost.***

In India, major problem is the small field size. More than 58 percent of operational holdings in the country have size less than 1ha. Only in the states of Punjab, Rajasthan, Haryana and Gujarat more than 20 per cent of agricultural lands have operational holding size of more than four hectare. There is a scope of implementing precision Agriculture for crops like, rice and wheat especially in the states of Punjab and Haryana. Commercial as well as Horticultural crops shows a wider scope for precision Agriculture.

In India, broadly two types of agriculture viz., high input agriculture characterized by the provision of assured irrigation and other agricultural inputs, and subsistence farming, which is confined mostly to rain-fed, or dry land regions, are prevalent. Nearly two-third arable land in India is rain-fed. The crop yields are very low (≈ 1 t ha-1) and very good potential exists for increasing productivity of rain-fed Cropping systems.

**6. Methodology**

Using a GPS along with a digital drainage map, the farmer is able to apply these pesticides in a safer manner. The spraying equipment can be preprogrammed automatically to turn off when it reaches the distance limitation or zone of the drainage feature. Additionally, farmers can preprogram the rate of pesticide or fertilizer to be applied so that only the amount needed determined by the soil condition is applied varying this rate from one area of the field to another. This saves money and allows for safer use of these materials.

Data collected by the GPS operations can be automatically recorded with the GIS program. Remotely sensed data can be analyzed and added to the GIS using soil maps, digital terrain and field operations information as ground truth. Additionally the farmers are able to record observations through the growing season such as weed growth, unusual plant stress or coloring and growth conditions. This can be used to guide further field operations like spraying, fertilizing and irrigating and it is part of the permanent record. Precision farming will make a strong impact on the way farmers manage their farm operations in the future.

**6.1 Seed spacing**

The yield from the seeds is maximum when adequate care is taken to adequately space them to enable each plant the optimum requisites for its growth, namely the soil nutrients, water, sunlight and protection against pest infestation. This is best accomplished by varying the seeding rate even within a single piece of land according to the soil conditions such as texture, organic matter and available soil moisture. One would plant fewer seeds in sandy soil as compared to silt loam soils because of less available moisture. The lower seed population usually has larger heads (ears) of harvested seeds providing for a maximum yield. Since soils vary even across an individual farm field, the ability to change seeding rates as one goes across the field allows the farmer to maximize this seeding rate according to the soil conditions. A computerized soil map of a specific field on a computer fitted on the tractor along with a GPS can tell farmers where they are in the field allowing the opportunity to adjust this seeding rate as they go across their fields.

**6.2 Steps to be taken for implementing PF in India:**

In the present existent situation, the potential of precision agriculture in India is limited by the lack of appropriate measurement and analysis techniques for agronomically important factors (National Research Council, 1997). 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 adoption of precision agriculture needs combined efforts on behalf of scientists, farmers and the government. The following methodology could be adopted in order to operationalise precision farming in the country.

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.

Realizing the potential of space technology in precision farming, the Department of Space, Government of India has initiated eight pilot studies in well-managed agricultural farms of the ICRISAT, the Indian Council of Agricultural Research and the Agricultural Universities, as well as in farmers' fields. The pilot studies aim at delineating homogeneous zones with respect to soil fertility and crop yield, estimation of potential yield, yield gap analysis, monitoring seasonally-variable soil and crop conditions using optical and microwave sensor data, and matching the farm inputs to bridge the gap between potential and actual yield through Spatial Decision Support Systems (SDSS). The test sites are spread over a fairly large area across a cross section of agro-climatic zones of the Indian sub-continent, and cover some of the important crops like wheat, rice, sorghum, pigeon pea, chickpea, soybean and groundnut.

The next step would be to generate detailed-level information on soil resources addressing potentials and limitations of individual fields since except for states like Punjab, Haryana, Madhya Pradesh and Maharashtra where fields size is quite large, practically individual field could be treated as a homogenous management unit for the purpose of precision farming.
Prior operational work in Remote Sensing with respect to agriculture has been undertaken by the space community which has been summarized by the following table.

**TABLE 1.** MAJOR INDIAN REMOTE SENSING MISSIONS FOR AGRICULTURE

| Mission | Year of launch | Sensors |
|---|---|---|
| IRS 1-A, 1-B | 1988<br>1991 | LISS-1(72.5resolution;148km Swath), LISS-11(36.25m resolution;142km swath) |
| IRS P2 | 1994 | LISS III( 36m resolution;142km swath |
| IRS IC,ID | 1995<br>1997 | PAN (5.8m resolution ;70m swath( LISS-111(23.5m;70.5m resolution; 141km ,148km swath) WiFS (188.3m resolution 774m swath) |
| IRS P3 | 1996 | WiFS (188.3 m resolution; 774km swath) |
| TES | 2001 | PAN(1m resolution; 14km swath) |
| RESOURCESAT-1 | 2001 | LISS-IV(6resolution;25km swath)A WiFS (80m resolution;800km swath) |
| CARTOSAT-1<br>(IRS-P5) | 2002 | PANStereo(2.5 km resolution;30km swath) |
| CARTOSAT-2 | 2003 | PAN Stereo (1km resolution; 12km swath) |

**6.3 DGPS Network:**

As a first step towards operationalization of PF, it is necessary to establish a DGPS infrastructure for the country. It would enable the farmers to get an accuracy of few centimeters in the various unit processes (sowing, fertilizer application, herbicide- pesticide application etc.,) involved in PF. A DGPS network would cater to the needs of multitude of applications (Meteorology, Transportation, Geodetic survey, Crustal Deformation studies, Disaster management and mitigation, etc.) of which PF is one. Each DGPS master reference is capable of providing the services within a radius of 100-kilometer radius. Hence, the number of master stations required to establish the DGPS infrastructure, which would cover the entire country, is calculated. This can be calculated as follows (only a random calculation)

Area of India = 329 million hectares.
Area of GPS (circular area, PI = 3.14) = PI * (100) ^2 sq. km.
= 31400 sq. km.
= 3.14 million hectares
Total no. of GPS reference stations required for the country = 329/3.14
Total GPS reference stations required = 105
Cost of a single DGPS set = Rs. 3 lakhs
Total cost of the entire infrastructure = Rs. 3.15 crores
this is affordable by any means for a country as a whole considering the innumerable applications it can cater. A simple assumed cost benefit analysis is carried out for precision farming, which is given below.

**6.4 Cost Benefit Analysis**

The real value for the farmer is that he can adjust seeding rates, plan more accurate crop protection programs, perform more timely tillage and know the yield variation within a field. These benefits will enhance the overall cost effectiveness of his crop production. Since the country is going to spend the amount, the GDP is considered rather than the farmer's personal income. Hence the cost-benefit analysis of the present project is

GDP of India for 1993 = $ 250.97 billion (FAO yearbook, 1994)
GDP in Indian Rupees = Rs. 12,924.955 billion
Amount spent for R&D = 0.3% of GDP = Rs. 38.775 billion
Cost-Benefit Analysis = 38.775 billion/315 million = **12,309**
Thus, it is proved that there is an enormous benefit in implementing the DGPS network, which would further pave the way for Precision Farming.

**7. Discussion and analysis**

"*Human Kind must rise above the earth to the top of the atmosphere and beyond. Only thus he fully understand the world in which he lives*"

– Socrates, 500 B.C.

Thus, precision farming has taken "***agriculture into the space age***". Farmers have services available that involve satellites collecting data, transmitting location information, or providing data from a variety of sources. Farmers can analyze this satellite information or they can rely on companies to do this service for them for a fee.

Precision farming is undoubtedly relevant to Indian agriculture in the context of improving agricultural production and Stakeholders' income and minimizing environmental impact. Geoinformation technology offers immense potential for deriving information on soil fertility, crop conditions and crop yield, crop simulation models enable estimating potential crop yield and the decision support system to facilitate developing appropriate prescription for improving crop production while minimizing the cost of inputs.

The major limitations of currently available high spatial resolution multispectral data are the fixed and broad spectral bands, very low repetivity, high cost which most of the Indian farmer could not afford. In order to match the technology with the requirement of precision farming, improvements in corresponding elements needs to be made to address the limitations to reap its benefits to fullest extent.

## 8. Conclusion

Agriculture has continued to be the cornerstone of Indian economy. In the years to come, precision agriculture may help the Indian farmers to harvest the fruits of frontier technologies without compromising the quality of land and produce. The adoption of such a novel technique would trigger a techno-green revolution in India which the need of the hour.

## 9. References

1) Chris J. Johannsen, April 1995. Precision Farming: Basic concepts Department of Agronomy Purdue University.

2) Hanson, L.D., Robert, P.C. and Bauer, M., 1995. Mapping wild Oats infestation using digital imagery for site-specific management. In Proc. Site-Specific Management for Agricultural System. 227-230, March 1994, Minneapolis, MN, ASA-CSA-SSSA, Madison, WI, pp.495-503.

3) Taylor, J.C., Thomas, G. and Wood, G.A., 1997. Diagnosing sources of within-field variation with remote sensing. In Precision Agriculture'97, Vol. II: Technology, IT and Management (Ed. J.V. Stafford). BIOS Scientific Publishers Ltd., Oxford, UK. pp.705- 712.

4) Moran, M.S., Inoue, Y. and Barnes, E.M., 1997. Opportunities and limitations for image –based remote sensing in precision crop management. Remote Sensing Env., 61, pp.319-346

5) Mulla, D.J., 1997. Geostatistics, remote sensing and precision farming. In Precision Agriculture: Spatial and Temporal Variability of Environmental Quality (Eds. J.V. Lake, G.R. Bock and J.A. Goode) John Wiley & Sons, New York, pp.100-119.

6) Ladha, J. K., Fischer, A. K., Hossain, M., Hobbs, P. R., Hardy, B., editors. 2000. Improving the productivity and sustainability of rice-wheat systems of the Indo-Gangetic plains: a systematic synthesis of NARS-IRRI partnership research. IRRI Discussion Paper Series No. 40.Makati City (Philippines): International Rice research Institute.31p.

7) Idso, S.B., Schmugge, T.J., Jackson, R.D., and Reginato.R.J., 1975. The utility of surface temperature measurements for the remote sensing of surface soil, water status. J. Geophys. Res. 80:3044-3049.

8) Ravi, N. and Jagadeesha, C.J., 2002, Precision Agriculture, Training course on Remote Sensing and GIS Applications in Agriculture, May 27th –7th June, 2002, RRSSC- Bangalore, pp: 225-228.

9) U.K.Shanwad, V.C. Patil, G.S. Dasog,C.P.Mansur and K.C.Shashidhar, GPS in Precision Farming, Dept. of agronomy, University of agricultural sciences,Dharwad,Karnataka.

10) Srvey of Indian Agriculture 2002, The Hindu..